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GUIDANCE AND CONTROL OF TACTICAL MISSILES

Thomas Alan Grote

NAVAL POSTGRADUATE SCHOOL

Monterey, California

THESIS

GUIDANCE AND CONTROL OF TACTICAL MISSILES

by

Thomas Alan Grote

December 1979

Thesis Advisor: D. J . Collins

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

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simulation ran and impact was recorded. An attempt at adding random noise to the homing seeker was tried, but revealed that more information is required on this topic. The MOD6DF computer program was successfully converted and altered to run using the simplified ramjet model.

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Guidance and Control of Tactical Missiles

by

Thomas Alan Grote
Lieutenant, United States Navy
B.S.A.E., United States Naval Academy, 1974

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN ENGINEERING SCIENCE

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December 1979

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This thesis discusses the conversion of the MOD6DF computer program for use on the IBM-360 computer at the Naval Postgraduate School. The functioning program was modified to investigate the impact miss distance for the Supersonic Tactical Missile. When the initial y-displacement error exceeded 1800 feet, the missile did not acquire the target. All errors smaller than this resulted in miss distances within 0.5 feet of the target. The midcourse guidance reference altitude was changed to reflect a sea-skimming missile. This simulation ran and impact was recorded. An attempt at adding random noise to the homing seeker was tried, but revealed that more information is required on this topic. The MOD6DF computer program was successfully converted and altered to run using the simplified ramjet model.

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TABLE OF SYMBOLS AND ABBREVIATIONS

The following is a list of the abbreviations and some of the more common fortran symbols used in the MOD6DF computer program. Each symbol is defined in two ways. The primary source of identification is by its COMMON(3415) location and the second is by its fortran symbol. The fortran symbol is not always a good identifier since it will change from subroutine to subroutine (i.e. W and WE both are used for missile weight).

A. ABBREVIATIONS

Symbol	Definition
TP	tangent plane axes
BA	body axes
SA	stability axes

B. FORTRAN SYMBOLS

Symbol	Definition
TXBA(073)	missile thrust in the x-direction in BA (lb)
TYBA(074)	missile thrust in the y-direction in BA (lb)
TZBA(075)	missile thrust in the z-direction in BA (lb)
W(086)	missile weight (lb)
S(110)	missile reference area (ft^2)
CA(111)	drag coefficient
CY(113)	side-force coefficient
CZ(115)	normal force coeffieient
CBAR(116)	mean aerodynamic chord (ft)
CMQ(118)	damping in pitch coeffieient
CNR(119)	damping in yaw coefficient

Symbol	Definition
CLP(120)	damping in roll coefficient
CM(121)	pitching moment coefficient
CN(122)	yawing moment coefficient
CL(123)	rolling moment coefficient
CGI(136)	center of gravity (ft)
A(201)	moment-of-inertia about missile roll axis (x-body axis) (slug-ft^2)
B(202)	moment-of-inertia about missile pitch axis (y-body axis) (slug-ft^2)
CC(203)	moment-of-inertia about missile yaw axis (z-body axis) (slug-ft^2)
TSA(208)	angle between SA and BA (rad)
P(212)	missile angular velocity about x-BA (rad/s)
Q(216)	missile angular velocity about y-BA (rad/s)
R(220)	missile angular velocity about z-BA (rad/s)
AG(282)	unit conversion lb-slug
VXTP(286)	missile velocity in x-TP (ft/s)
XTP(290)	missile displacement in x-TP (ft)
VYTP(294)	missile velocity in y-TP (ft/s)
YTP(298)	missile displacement in y-TP (ft)
VZTP(302)	missile velocity in z-TP (ft/s)
ZTP(306)	missile displacement in z-TP (ft)
GZRO(404)	constant set to zero for flat earth gravitational field and set to one for a spherical gravitational field
ER(405)	angular velocity of earth (rad/s)
ALPO(406)	angle between north and x-TP (rad)

Symbol	Definition
OLAMO(407)	latitude origin of tangent plane
HO(414)	distance tangent plane is from earth (ft)
GO(415)	gravitational acceleration (ft/s^2)
HREF(501)	reference altitude for midcourse guidance (ft)
RE(503)	earth's radius (ft)
H(507)	altitude normal to earth (ft)
AMACH(520)	missile Mach number
THET(521)	missile pitch angle, TP (rad)
PSI(522)	missile yaw angle, TP (rad)
PHI(523)	missile roll angle, TP (rad)
GAMMAV(527)	vertical flight path angle, TP (rad)
VEL(528)	magnitude of missile velocity (ft/s)
VAT(529)	missile velocity (ft/s)
TF(550)	program termination time (s)
VAH(561)	computed speed of sound (ft/s)
ALAT(576)	latitude of target position (deg)
AZ(578)	azimuth of target position (deg)
DYNP(581)	dynamic pressure (psi)
FLGRJ(606)	constant set to zero indicates run will use ENGINE subroutine and when set to one run will use RAMJET subroutine (simplified ramjet model)
T(932)	actual time (s)
T1(933)	boost engine ignition (s)
T2(934)	commence acceleration command mode (s)
T3(935)	boost engine burn-out/port cover blow-in (s)
T4(936)	start ramjet engine (cruise) (s)
T5(937)	commence heading and altitude guidance control (s)

Symbol	Definition
T6(938)	commence terminal dive (s)
T7(939)	commence terminal guidance - search (s)
T8(940)	commence terminal guidance - track (s)
DMAX(1740)	maximum fin deflection (rad)
CPP(2669)	time between printouts (s)
ROLLO(2901)	initial roll angle (rad)
PITCHO(2902)	initial pitch angle (rad)
YAWO(2903)	initial yaw angle (rad)
STEP(2905)	determines executive program flow after staging
DOC(2909)	defines number of times COMMON will be printed
HMIN(2911)	minimum integration step size
HMAX(2912)	maximum integration step size
DER(1)(2913)	integration step size (s)

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I. INTRODUCTION

Research was undertaken to convert the MOD6DF computer program received from NWC China Lake for use on the IBM-360 computer at the Naval Postgraduate School. Once a functioning program was obtained, initial displacement error versus impact miss distance was investigated for the supersonic tactical missile. Additionally, the midcourse guidance reference altitude was changed to reflect a sea-skimming scenario and this was examined for its effect on the terminal guidance problem. This report not only discusses the aforementioned topics, but also describes the missile mission requirements and the MOD6DF computer program.

II. MISSION REQUIREMENTS

The Supersonic Tactical Missile (STM) mission is divided into six phases (Ref. 1).

- initial conditions
- separation
- boost
- transition
- cruise
- terminal

These divisions are based on the missile aerodynamics. The initial condition phase establishes the starting conditions for each launch. This is done while the missile is still attached to the launch platform. The separation phase starts when the missile is launched. The missile falls for approximately five seconds until the boost engine ignites. This initiates the boost phase which continues until the missile achieves Mach two. As the missile passes through Mach one, plume effects are encountered which the aerodynamics account for. At the end of the boost phase, the port covers blow in. This initiates the transition phase. This phase is very short and allows the debris to be ejected from inlet ports. The cruise phase commences when the ramjet engine ignites. This engine propels the missile until target impact. The terminal phase of the flight begins when the missile is commanded to dive from the cruise altitude. This phase concludes when the flight is terminated at target impact.

The six STM mission phases require four phases of control. These control phases are:

- separation
- midcourse guidance
- terminal dive
- terminal guidance

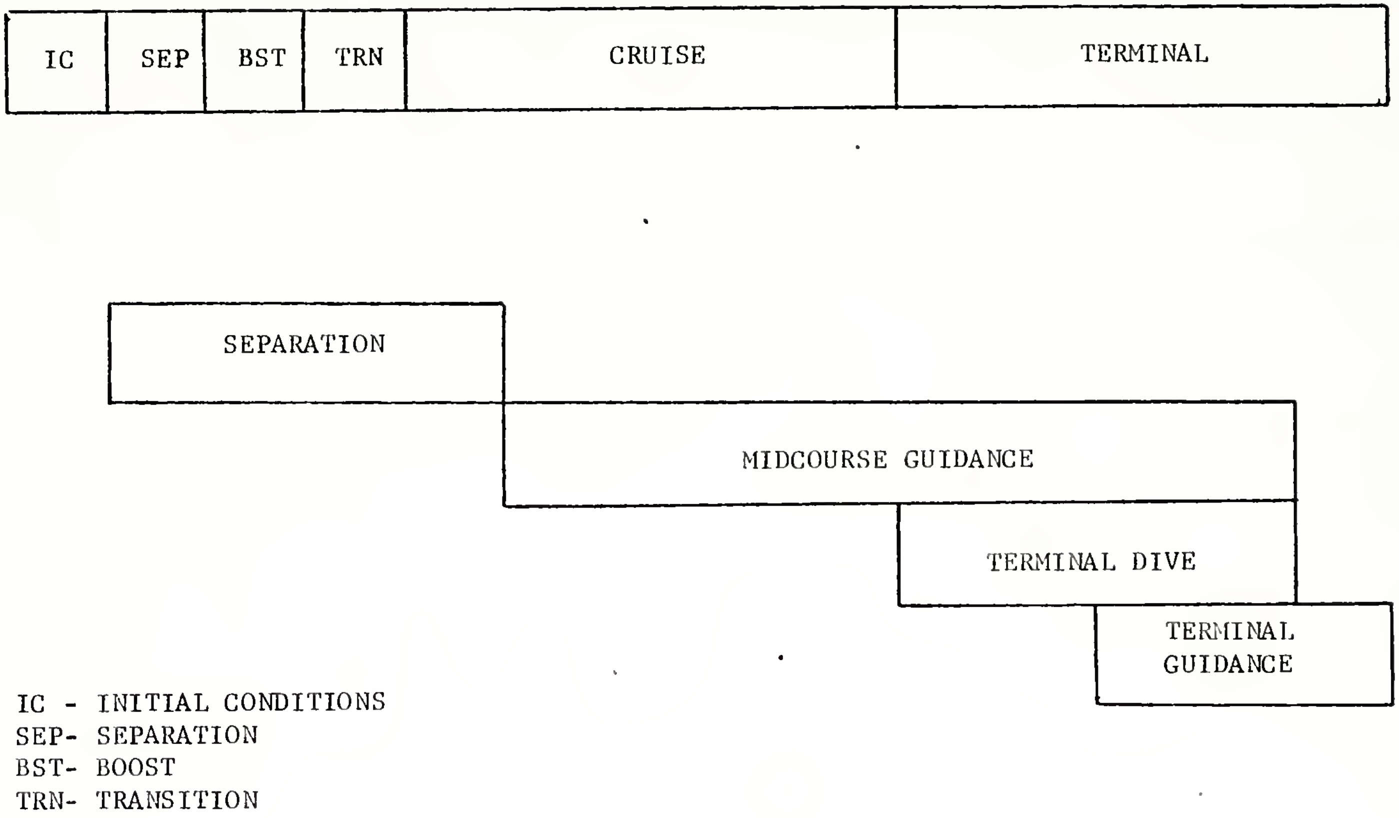
The four Guidance, Navigation, and Control (GN&C) system control phases are directly related to the mission phases. Figure 1 displays this relationship (Ref. 2). To obtain a successful flight, various types of control and guidance functions are required. Figure 2 (Ref. 3) illustrates the guidance control mode sequencing in relation to the mission phases and also indicates the critical missile switching times. The control phases are discussed below, along with the appropriate guidance modes.

A. SEPARATION

The separation phase commences upon launch. The missile is ejected downward from the launch platform. Additionally, the pitch attitude of the missile is commanded down. Since this portion of the flight is unguided, the ejection force and gravity are the only forces acting on the missile. At launch, the missile is required to be in the attitude command mode.

Five seconds into the flight, the missile pitch attitude is commanded up and the boost engine is ignited. The booster continues until the missile attains Mach two, at which time control is shifted from attitude to acceleration control mode. The acceleration control then requires the missile to maintain the normal and lateral accelerations at zero.

The last event to occur in the separation phase is inlet port cover blow-in. The time delay that allows the port covers to clear is a function of altitude.



CONTROL PHASES/MISSION PHASES
RELATIONSHIP

FIGURE 1

t_0 - LAUNCH: START SIMULATION

t_1 - BOOSTER IGNITION

t_2 - CONTROL SYSTEM MODE CHANGE FROM ATTITUDE TO ACCELERATION CONDITION AT M=2.0

t_3 - PORT COVER BLOW-IN, BOOSTER BURNOUT

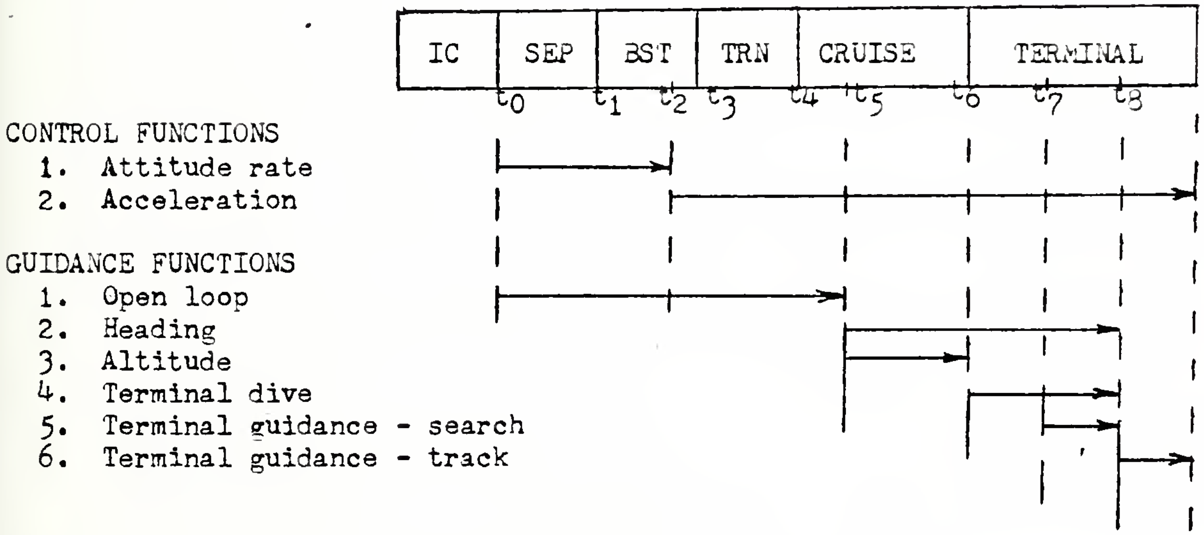
t_4 - RAMJET IGNITION, t_3 + .3 sec

t_5 - ENGAGE FUIDANCE MODES

t_6 - DIVE COMMAND

t_7 - SEEKER SEARCH MODE IS ACTIVATED

t_8 - TERMINAL TRACKING



FLIGHT MODE SEQUENCING

FIGURE 2

B. MIDCOURSE GUIDANCE

Midcourse guidance begins upon completion of the separation phase. The moment the port covers are clear, the phases shift. During this phase two things are required. The GN&C must guide the missile to the established cruise altitude and then guide the missile (in the horizontal plane) to the predetermined target location.

To accomplish these requirements the GN&C system employs both altitude and heading control. The altitude control acts upon the pitch axis to drive the missile to the cruise altitude and then to maintain that altitude until the terminal dive phase commences.

The actual guidance work is performed by the yaw axis. The GN&C system uses the heading control to steer the missile to the target position. To generate the steering commands a guidance law is necessary. The guidance law should minimize the cross-track error and the final lateral acceleration. A minimum cross-track error allows for minimum flight time and minimum displacement error when target search is initiated. Minimizing the final lateral acceleration ensures that the seeker will continuously be pointing toward the target area. To insure accuracy, the guidance law must be able to perform these functions when subjected to disturbances such as wind and thrust misalignment.

C. TERMINAL DIVE

The terminal dive phase commences when the missile is commanded to dive. The actual time that this command is given is a function of the predetermined target coordinates. Upon diving, the missile must accelerate downward along a 60-degree (from horizontal) dive angle to the target position. Once the missile has steadied up in the proper dive aspect, terminal guidance commences.

D. TERMINAL GUIDANCE

During the terminal guidance phase the seeker is required to search, acquire, and track the target. The GN&C system then uses these tracking signals to direct the missile to the target. The seeker uses a preprogramed search pattern to locate the target. When the target has been acquired, the seeker then commences tracking it and also notifies the GN&C system that the target is being tracked.

Target acquisition takes place when the target falls within the instantaneous four-degree beamwidth pattern as it traverses the scan pattern on the earth's surface. The computer program uses this assumption since the exact missile target acquisition mechanism has not yet been defined.

Upon acquisition, the GN&C system closes the seeker tracking loop. The radiometer error signal is defined as the difference between the look vector and the line-of-sight. This signal is used to reposition the antenna gimbals so the look vector and the line-of-sight coincide. Under the closed loop operation the radiometer output is proportional to the line-of-sight rate and this is the signal used to guide the missile to target impact.

III. COMPUTER SIMULATION

The modularized six-degree-of-freedom (MOD6DF) computer program was developed by the Litton Systems, Inc., Guidance and Control Systems Division (Ref. 4) to be used in analyzing missile guidance and control. The program uses a building block approach, where each module corresponds either to a missile subsystem or an environmental system. In its original form, the program is used primarily for terminal guidance of air-to-surface missiles. The Naval Weapons Center, China Lake modified the original program to specifically apply to the Supersonic Tactical Missile (STM). The modification also allows the user the capability of simulating any portion of the missile flight trajectory.

The MOD6DF computer program consists of four main decks and one auxiliary deck. The main decks include the executive programs, operational subroutines, modules, and input data deck. All the subprograms utilized in the integration and the sequencing of the modules are contained in the executive programs. The operational subroutines are used by the user to control the program while it is running. The psysical system and the environmental subroutines are included in the modules. The input data deck contains all the information the executive programs need to execute the desired run. Lastly, the auxiliary deck consists of all those subprograms (subroutines and functions) that are required by the modules.

Once the user starts making simulations, he must concern himself with program sequencing. Proper sequencing is required to ensure a valid run is achieved. Since it is of such importance, sequencing will be discussed as the final part of this section.

A. EXECUTIVE PROGRAMS

The executive programs are the main core of the MOD6DF program. These subroutines have various functions in setting up, sequencing, integrating, and resetting the program. Since these functions are required by any type of analysis done, the user should never have to change any of these subroutines. Reference 5 should be consulted if the user desires more information about the content of any of the subroutines described herein.

1. Zero

Subroutine ZERO is used to set all the COMMON(3415) locations to the value zero. This is done to ensure that no erroneous information is used in the simulation.

2. Oinpt1

Subroutine OINPT1 is the basic input routine for the MOD6DF program. The normal input is from punched cards. However, inputs may also be read from tapes. The basic input cards will be discussed in the section covering the input data deck.

3. Auxi

Subroutine AUXI is used to call the initialization modules for each run. Additionally,, it sets up the list of state variables which are used in AMRK.

4. Auxsub

Subroutine AUXSUB is used to call the dynamic modules. In calling the dynamic modules, AUXSUB sets and resets the lists needed for AMRK and the COMMON(3415) storage cells with the most recent values of the state variables and their derivatives.

5. Amrk

Subroutine AMRK is the integration subroutine. It uses a pointwise first order Runge-Kutta method. All the state variables to be integrated must be listed in COMMON(3415) and also must appear in a processing list.

6. Reset

Subroutine RESET is used to reinitialize up to fifty input parameters. This is done prior to the start of any repeated runs. To indicate which parameters are to be reset, the number one is punched in columns 46-60 on the respective type three card.

7. Return Group

The return group is a collection of all the unused modules. Since all the modules and their initialization modules are called by AUXI and AUXSUB, the unused ones must still remain in the deck. These are required to ensure proper linking when the computer attempts to link all the subroutines. All the subroutines in this grouping contain three cards. The three cards are the subroutine title, and a return and an end card.

8. Subl1, Subl2, Subl3

These subroutines are used to call the operational subroutines that are required. They call the routines in the order prescribed by the input data deck. The number at the end of each subroutine title indicates which operational subroutines it can call. For example, SUB11 can call STGE1.

B. OPERATIONAL SUBROUTINES

The operational subroutines provide the user with control of the program while it is running. The order in which the operational subroutines are called is specified by the input data deck. Since these routines assist the user in controlling the simulation, they can be reprogrammed. However, it is advised that they not be changed until the user has become quite familiar with the overall operation and sequencing of the MOD6DF program. For more in depth knowledge of the operational subroutines the user should consult Ref. 6, and the computer listing, which is contained at the end of this report.

1. Inpt1, Inpt2, Inpt3

These subroutines are available for new inputs during the simulated flight. The only one presently used in the program is INPT1. It is utilized to input a namelist file.which is used by ENGINE and is described there.

2. Oupt1, Oupt2, Oupt3

These subroutines allow for the print-out of up to fifty different variables during the flight simulation. OUPT1 is not utilized in the deck. OUPT2 is used when the desired output is to be put on tape. OUPT3 is the basic output routine. It prints the desired output on regular computer paper.

3. Stge1, Stge2, Stge3

These subroutines allow for proper staging, run termination, etc.. Presently STGE1 is not being used. STGE2 is being used as the staging initialization subroutine. STGE3 is the primary subroutine of this group. It stages when impact with the earth is made, when the final time, TF(550), is reached, or when LCONV(2672) is set equal to two. All the tolerances for staging are listed in STGE3.

4. Cntrl, Cntr2, Cntr3

These subroutines allow the external dynamic control inputs to the modules. In the MOD6DF program these are not used.

5. Rndml, Rndm2, Rndm3

These subroutines allow random noise to be added to the state variables generated in the modules. RNDM1 is not used in the program. RNDM2 is used as the initialization subroutine, while RNDM3 provides continous noise values. These subroutines produce correlated noise values for as many modules as required. The noise values remain fixed during each individual integration cycle.

6. Auxa1, Auxa2, Auxa3
Auxb1, Auxb2, Auxb3
Auxc1, Auxc2, Auxc3

These subroutines are auxiliary routines that allow for external input, output, control, etc. of the modules. At the present time, none are utilized in the MOD6DF program.

C. MODULES

The modules are of prime importance to the user since they represent the 'model' of the dynamic system. In general, the model is described by ordinary non-linear time-varying differential equations with both random and deterministic forcing functions. The user must first reduce these equations to an equivalent system of first order equations, which can then be described by each module. Generally speaking, the physical system is so complex that this would be impossible to do. However, due to the modularity of the MOD6DF program, the user can think of each module as a completely independent system described by the equations within that module.

There are thirty-six possible modules divided into five functional

categories. Each group is identified by a letter which pertains to that groups function; A (airframe), C (computers), D (dynamics), G (geophysical), S (sensors). A complete printing of each module is contained in the computer program listing.

1. Airframe

a. Subroutine A1

This is the aerodynamic forces and moments modules. It calculates all the necessary forces and moments in body axes. These values are then used in the computation of the dynamics.

b. Subroutine A2

This is the missile aerodynamic coefficient module. It calculates the required coefficients using the information stored in the BLOCK DATA. Using the timing inputs, this routine computes the coefficients for the different effects. Some of the effects accounted for are; plume, separation, and control surfaces effectiveness. With this done the total coefficients are determined.

c. Subroutine A3

This is the missile propulsion module. The timing inputs are used to determine whether the missile is in free fall, boost, transition, or cruise phase. With this determined the correct engine subroutine (BOOST, RAMJET, ENGINE) can be called. Three variables are calculated using the body axes as the frame of reference. They are the missile thrust is all coordinate directions, the principal moments of inertia, and the missile weight.

d. Subroutine A4

This is the fin actuator module. The four control surfaces commands are calculated as either ideal actuators or as second-order

ones. In addition to control surfaces commands, the rate of change of yaw, and roll are computed.

e. Subroutine A5

This module is part of the return group.

2. Computers

a. Subroutine C1

This is the autopilot module for the STV-G. It uses the cruise engine ignition time to divide the routine into boost/separation and cruise phases. These two phases use different algorithms to calculate the turning moments in pitch/yaw and roll.

b. Subroutine C2

This is the guidance command module. Using the timing inputs, this routine is divided into separation/boost, dive/climb, cruise, terminal dive, and terminal homing sections. Each section uses slightly different algorithms to calculate the guidance commands to maintain the proper flight profile.

c. Subroutines C3 - C10

These modules are part of the return group.

3. Dynamics

a. Subroutine D1

This is the translational dynamics module. It computes the total acceleration in body axes and then converts them to the tangent plane reference. Then, accounting for aerodynamics, thrust, gravity, and coriolis, the velocity and acceleration are calculated.

b. Subroutine D2

This is the rotational dynamics module. With the principal axes as a reference, this subroutine computes the body angular rates and the attitude direction cosines.

c. Subroutines D3 - D5

These modules are part of the return group.

4. Geophysical

a. Subroutine G1

This is the gravitational and coriolis acceleration module. It calculates the gravitational acceleration using one of two fields. The user specifies the field to be used by an input card. To use a flat-earth gravitational field, GZRO(404) must equal 0.0, and to use a spherical gravitational field, GZRO(404) must equal 1.0.

b. Subroutine G2

This module is part of the return group.

c. Subroutine G3

This is the air data module. It computes the velocity, in all three coordinate directions, with respect to the air mass. These values are then resolved into body and stability axes. This module also computes all the properties of air by calling subroutine AIR. These values are stored in their COMMON(3415) locations for use in the other modules.

d. Subroutine G4

This module is part of the return group.

e. Subroutine G5

This is the coordinate conversion module. It takes the missile position, does a coordinate conversion and then it determines the position, velocity, and acceleration in the ECI system.

f. Subroutine G6

This module is part of the return group.

5. Sensors

a. Subroutine S1

This is the homing seeker module. It simulates the missile seeker and computes the seeker dynamics and Euler angle rates. Several flags are used to control the seeker sequencing:

(1) FLAGS(335). FLAGS signals the start of the seeker search.

(2) FLGT(317). FLGT signals when the seeker is locked-on.

(3) FLGTS(347). FLGTS signals the end of search.

(4) FLGD(336). FLGD signals when the seeker has detected the target.

(5) FLAGLT. FLAGLT signals when the target is outside the seeker field of vision.

b. Subroutine S2

This is the radiometer module. It takes the target position and the ATIGS target position and converts them from body axes to the seeker axes. Using target position, the module then calculates the azimuth and elevation error signals.

c. Subroutines S3, S4

These modules are part of the return group.

d. Subroutine S5

This is the accelerometers and gyros modules. The user has the option of using ideal or digital accelerometers. To specify the type of accelerometer, the user must include the appropiate data statement in the subroutine. If ideal accelerometers are desired, FLGA must equal 0.0 and for digital accelerometers, FLGA must equal 1.0.

e. Subroutines S6 - S10

These modules are part of the return group.

D. INPUT DATA DECK

The input data deck provides the user with the means of specifying which operational subroutines and modules are to be utilized for the desired run. It also allows the user to set the starting conditions. In general, only the constants and the state variables must be given initial values. All quantities in COMMON not given initial values will be set to zero by ZERO. In addition to the state variables, the upper and lower error bounds must be initialized. There are seven types of input cards, each indication a certain function.

Type	Function
0	read/write tape
1	operational subroutine to be called
2	module to be called
3	numerical input
4	printed output
5	parameter square and sum
6	termination and random noise generator input

A separate card is required for each subroutine, module, input, and output quantity. A sample computer printout of the input data deck is contained in the computer output section.

1. Type 0 Card

Type 0 cards are used to indicate if the type 3 inputs are to be read from or written onto an auxiliary tape. These procedures can be used rather than reading the inputs from a deck of cards. A typical card is defined by punching a zero in column 2. The field that covers columns 5 - 20 is used by the user for any descriptive statements with which he wishes to identify the input. Column 21 -25 contains the right-

justified integer number of the tape transport to be used. The number of the first record to be read is punched in column 31 - 45. The last field is column 46 - 60 which contains the number of records to be read. The last two fields may use either fixed or floating-point notation.

2. Type 1 Card

Type 1 cards are used to specify which operational subroutines are called during the flight simulation. This type card is identified by the number one in column 2. The second field is column 5 - 20 which contains any identifying information. This information is printed out when the data deck is read and allows the user to read exactly which subroutines were called. Column 21 - 25 contains the right-justified integer number which is the subroutine identifying number. The operational subroutine numbers are;

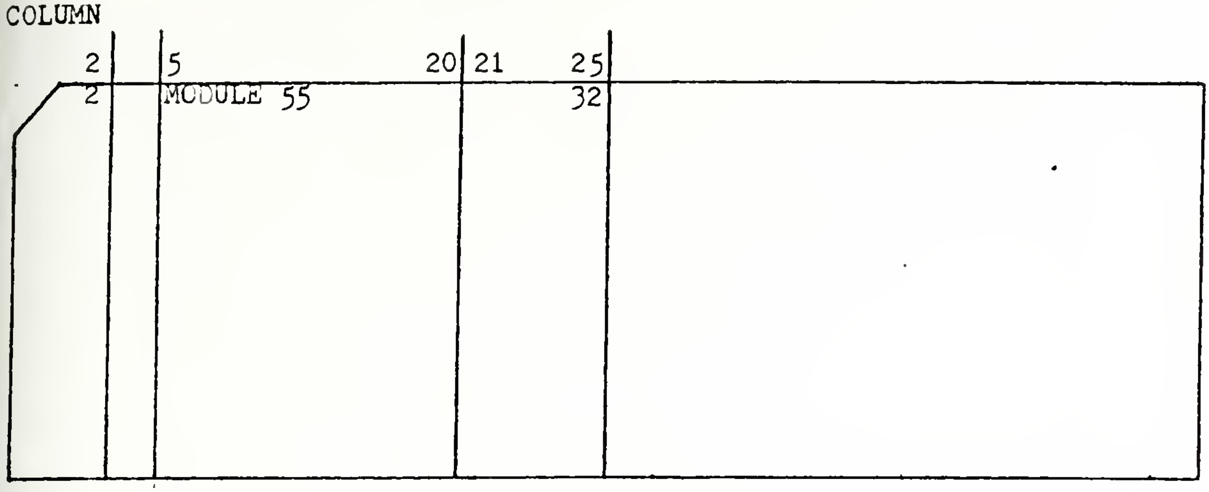
Subroutine	Subroutine Number
INPT1, INPT2, INPT3	2
OUPT1, OUPT2, OUPT3	3
STGE1, STGE2, STGE3	4
CNTR1, CNTR2, CNTR3	5
RNDM1, RNDM2, RNDM3	6
AUXA1, AUXA2, AUXA3	7
AUXB1, AUXB2, AUXB3	8
AUXC1, AUXC2, AUXC3	9

It should be noted that all or any of the subroutines listed under one one number can be called by including only one card. The cards are placed in the data deck in the order in which they will be called. This order or sequencing will be explained further in section F, Sequencing. A typical type 2 card is identified by the number two in

column 2. In general, column 5 - 20 should contain the module title, but any pertinent information is allowed. The module number is punched in column 21 - 25 and it must be right-justified. A listing of the module numbers follows:

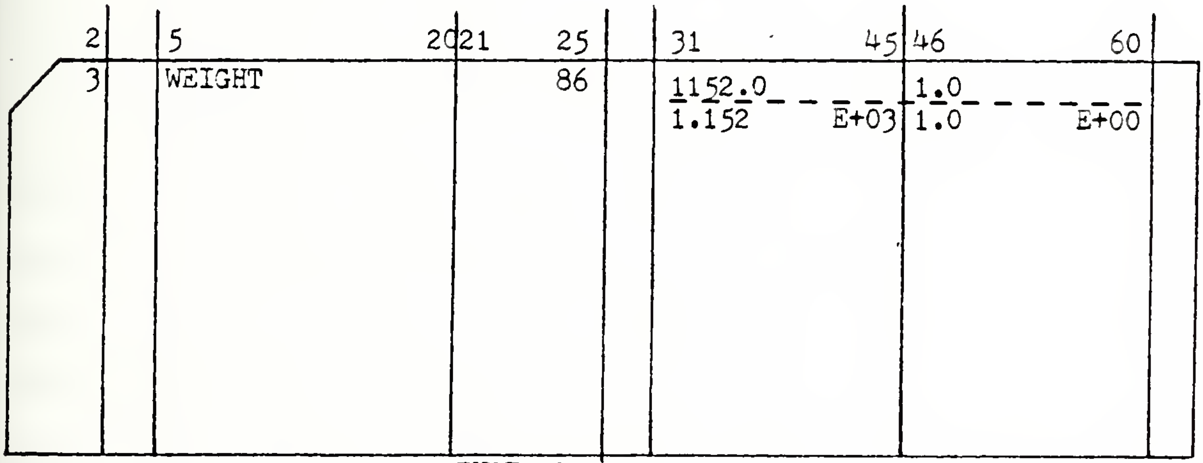
Module	Module Number	Module	Module Number
A1,A1I	2	D4,D4I	20
A2,A2I	3	D5,D5I	21
A3,A3I	4	G1,G1I	22
A4,A4I	5	G2,G2I	23
A5,A5I	6	G3,G3I	24
C1,C1I	7	G4,G4I	25
C2,C2I	8	G5,G5I	26
C3,C3I	9	G6,G6I	27
C4,C4I	10	S1,S1I	28
C5,C5I	11	S2,S2I	29
C6,C6I	12	S3,S3I	30
C7,C7I	13	S4,S4I	31
C8,C8I	14	S5,S5I	32
C9,C9I	15	S6,S6I	33
C10,C10I	16	S7,S7I	34
D1,D1I	17	S8,S8I	35
D2,D2I	18	S9,S9I	36
D3,D3I	19	S10,S10I	37

Note that either the module, the initialization module, or both may be called by including only one card in the deck. A sample of a typical type 2 card is shown in Figure 3 (Ref. 7).



TYPICAL TYPE 2 CARD

FIGURE 3



TYPICAL TYPE 3 CARD

FIGURE 4

4. Type 3 Card

Type 3 cards are used to set any COMMON(3415) location to any value other than zero. In general, four items must be initialized. The state variable initial values and any constants used in the flight simulation are the most obvious. Additionally, there are some constants associated with the executive programs and operational subroutines and the state variable upper and lower bounds which must be initialized. As with all cards, column 2 defines the type card and it must contain a three. Column 5 - 20 holds the statement describing the input. The user should be specific here since it will save him having to remember every COMMON(3415) location. The only other means of input identification is by column 21 - 25. These columns contain the right-justified COMMON location of the input. Columns 31 - 45 hold the actual numerical value of the input. The last field, column 46 - 60, contains the reset flag. If the reset flag equals one, the COMMON(3415) location and the numerical value are placed in the reset list. This list may contain up to fifty different variables. This, in the case of multiple runs, allows the variables to be reset to its initial value prior to each run without additional input cards. The sample card in Figure 4 (Ref. 8) shows that either fixed or floating-point notation may be used to input the numerical value and the reset flag. These cards need not be inputed in any specific order, but for ease of checkout, it is advised to place them sequencially by their COMMON location.

5. Type 4 Card

The MOD6DF program can printout a maximum of fifty variables for each simulation. Type 4 cards are used to specify which variables are to be printed. Column 2 must contain the number four to indicate a type

4 card. When the results are printed out headings are included. These headings are designated in column 9 - 20. The exact alphanumeric title punched will be printed at the top of each page, this need not be the fortran symbol used within the program. The COMMON(3415) location of the output variable is contained in column 21 - 25 and must be right-justified.

6. Type 5 Card

Type 5 cards are used to indicate which variables are to be root-mean-squared. These cards are similar to type 1 and type 2 cards. Column 2 must contain the number five. Any pertinent information about the variable to be operated on is punched in column 5 - 20. The COMMON (3415) location of the variable must be right-justified in columns 21 - 25. The last field, column 31 - 45, indicates whether the root-mean-square operation will occur along the trajectory or at the end.

7. Type 6 Card

The type 6 card has two purposes. Its first function is trivial, but required. The number six is typed in column 2 and the rest is blank. This indicates to the computer program that there are no more input cards. Its second function involves random inputs. This card is used to indicate the number of random process (noise) generator cards that are to be read before the input process is terminated. Column 2 has the same information as before. Any pertinent information is contained in column 5 - 20. Columns 21 - 25 must be right-justified and they contain the number of random generator cards to be read.

E. AUXILIARY DECK

The auxiliary deck is a collection of subroutines and functions required by the modules. These routines are general in nature since

they can be called by several modules. They are used to calculate such things as the properties of air, engine performance, various ratios, and to locate values in the many data tables. A brief discussion of the most common subroutines is presented.

1. Boost

This subroutine calculates the thrust coefficient (CT) and the fuel flow rate (FF) during the boost phase. These values are returned to module A3 and used to calculate the missile thrust in the body axes and the missile weight.

2. Ramjet

This subroutine is used during the midcourse, cruise, phase of the missile flight. It uses a simplified ramjet model to calculate the thrust coefficient and fuel flow rate. This routine is not automatically called. The user must designate that he wishes to use it by inputing a type 3 card setting FLGRJ(606) equal to one. This then sets up the proper stepping in module A3.

3. Engine

This is the primary routine during the cruise phase. It is one of many routines within the NWC air-breathing propulsion package. This entire package is utilized to calculate the engine parameters from inlet to exhaust. Again, thrust coefficient and fuel flow rate are eventually computed and returned to module A3. The user does not need to supply any special input cards to use this subroutine. If no initial value is inputed for FLGRJ(606) it is automatically set to zero, which indicates this routine is to be used.

4. Air

All the properties associated with the air are calculated in

this subroutine. This includes the computation of the speed of sound and the dynamic pressure. Since the missile does vary in altitude, the routine takes this into account as well as the latitude. Once these values are calculated, they are returned to module G3.

5. Block Data

This routine contains data tables. These tables cover parameters from aerodynamic coefficients to thermal properties. The total data package covers specific bands within the missile operating envelope. Data is stored in matrices which includes one, two, and three dimensional ones. These data tables are readily available and there are routines designed to retrieve this information quickly.

6. Serch

This subroutine, along with several functions, is used to retrieve information from BLOCK DATA. If the present operating point of the missile is not within one of the bands of information, then the tables are interpolated. The functions THREDL, STDLI, STDLIA, and TAB do the interpolation of the tables. Since the tables are of various lengths, these functions are very general.

F. SEQUENCING

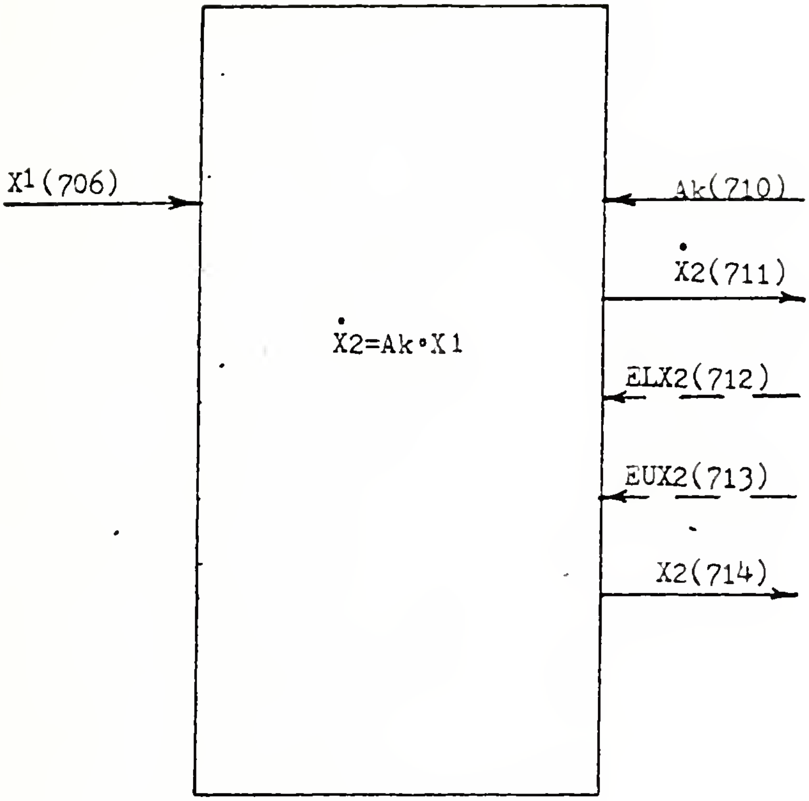
Sequencing is very important in the running of the MOD6DF program. Care must be taken to ensure that the modules are processed in the correct order at each step. This is essential to eliminate the use of obsolete values from the last cycle. An exception to this problem is the state variables. These are updated simultaneously by the integration algorithm. Any module is capable of using the most current value of these, no matter what the order of processing.

To help remedy this problem, module diagrams were devised. Module

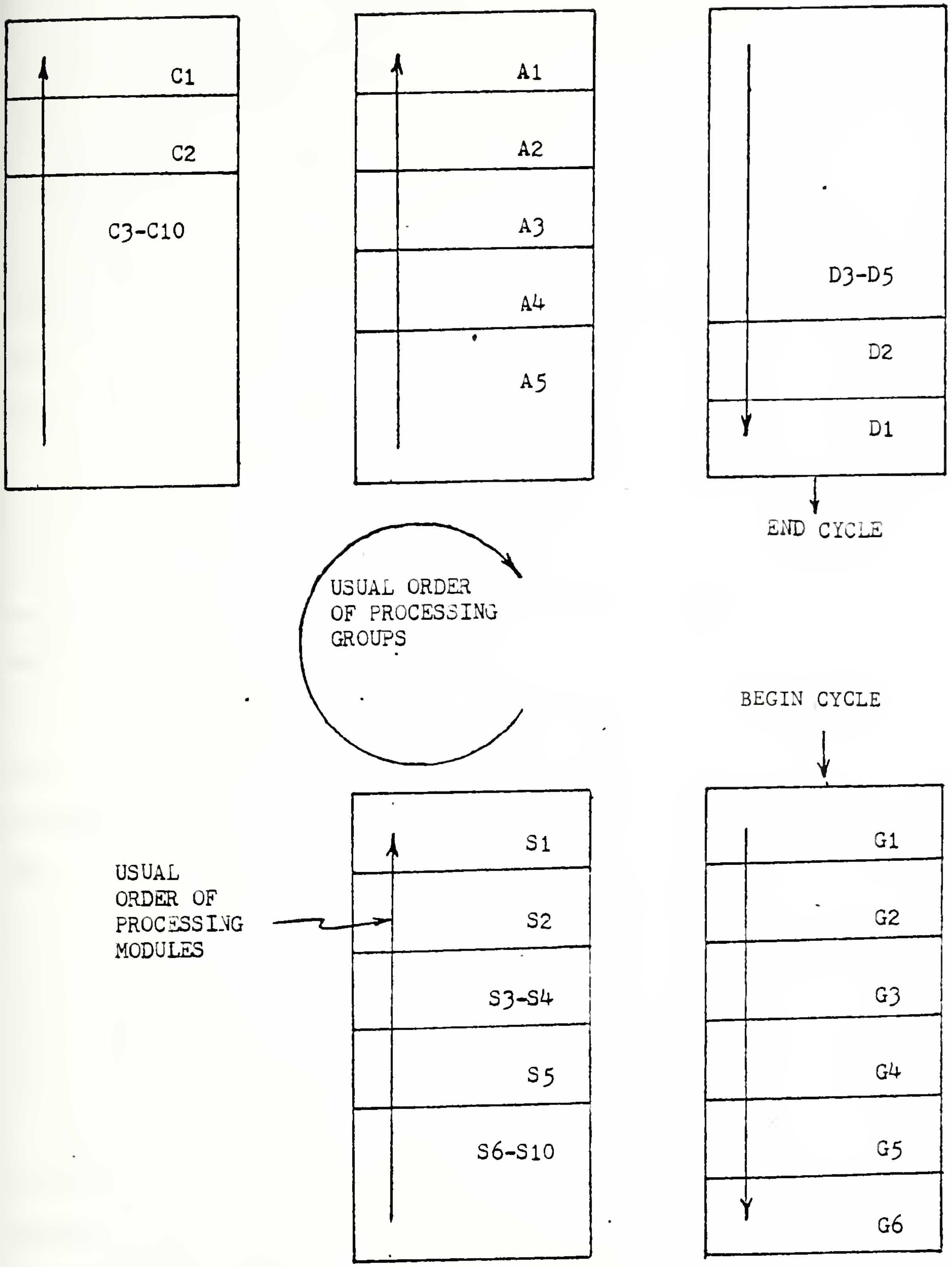
diagrams aid the user in maintaining the proper flow of variables into and out of the modules. To design a module diagram start with a box. This box will contain all the equations for a specific module. The standard procedure for showing inputs and outputs is to use arrows pointing in or out from either the left or the right side. The example in Figure 5 (Ref. 9) shows this technique. The arrows pointing in from the left indicate variable inputs from other modules. Arrows pointing out to the right indicate output going to either other modules or program output. The last set of arrows points in from the right. These show the constants brought in directly or indirectly from the initialization module. Since each arrow represents a variable, they must be defined. The usual means of labeling the arrows is to use the variable fortran symbol and in parenthesis its COMMON(3415) location.

Each variable usually has only one COMMON location associated with it. In the case of 'state' variables this is not true. State variables are defined by four consecutive COMMON locations. The first is for the derivative of the variable. The second and the third locations hold the lower and upper bounds, respectively, of the integration error. The last one contains the variable itself.

Once all the required module diagrams have been completed, they can be combined to get the overall processing order. The usual processing order, shown in Figure 6 (Ref. 10) is to start with the geophysical group, then proceed to sensors, computers, airframe, and finally dynamics. Within each group is a usual processing order and this too is shown in Figure 6. This process for determining the program sequence will eliminate the use of any obsolete values in the computer run.



MODULE DIAGRAM
FIGURE 5



PROCESSING SEQUENCE

FIGURE 6

IV. COMPUTER PROGRAM CHECKOUT

The basis for the research was the MOD6DF computer program from NWC China Lake. The total package received from them consisted of a listing of the program and an uninterpreted deck of cards. The initial step was to input the cards in small groups into the computer and then to examine the source listing. This listing revealed that the original deck was punched in BCD. This fact was easy to determine since several characters were changed (Ref. 11). The library routine NEWDEK was used to translate the cards from BCD to EBCDID.

Once the translation was completed, an attempt was made to compile the new deck. This produced an output which contained many syntax errors. These errors were divided into two major groups. One effected the use of quotation marks in FORMAT and comment statements. The other one, the more difficult, effected the DATA statements in the BLOCK DATA subroutine.

The problem with the DATA statements was due primarily to the difference in the compilers used. The compiler at NWC was much newer and allowed for the use of more sophisticated inputs. The compiler at NPS only allows a data set to start with the first element. This required the rewriting of many data groups. To complicate these revisions, a limit of nineteen continuation cards is also imposed. These restrictions demanded not only the rewriting of many data sets, but also the formation of two new ones.

With the corrections finally completed, the computer would then compile the program. The next step was to link all the subroutines together. The first attempt was unsuccessful. Inadvertently, the subroutine INTR20 had been omitted from the original deck. Using the program listing, the contents of INTR20 were typed and included in the

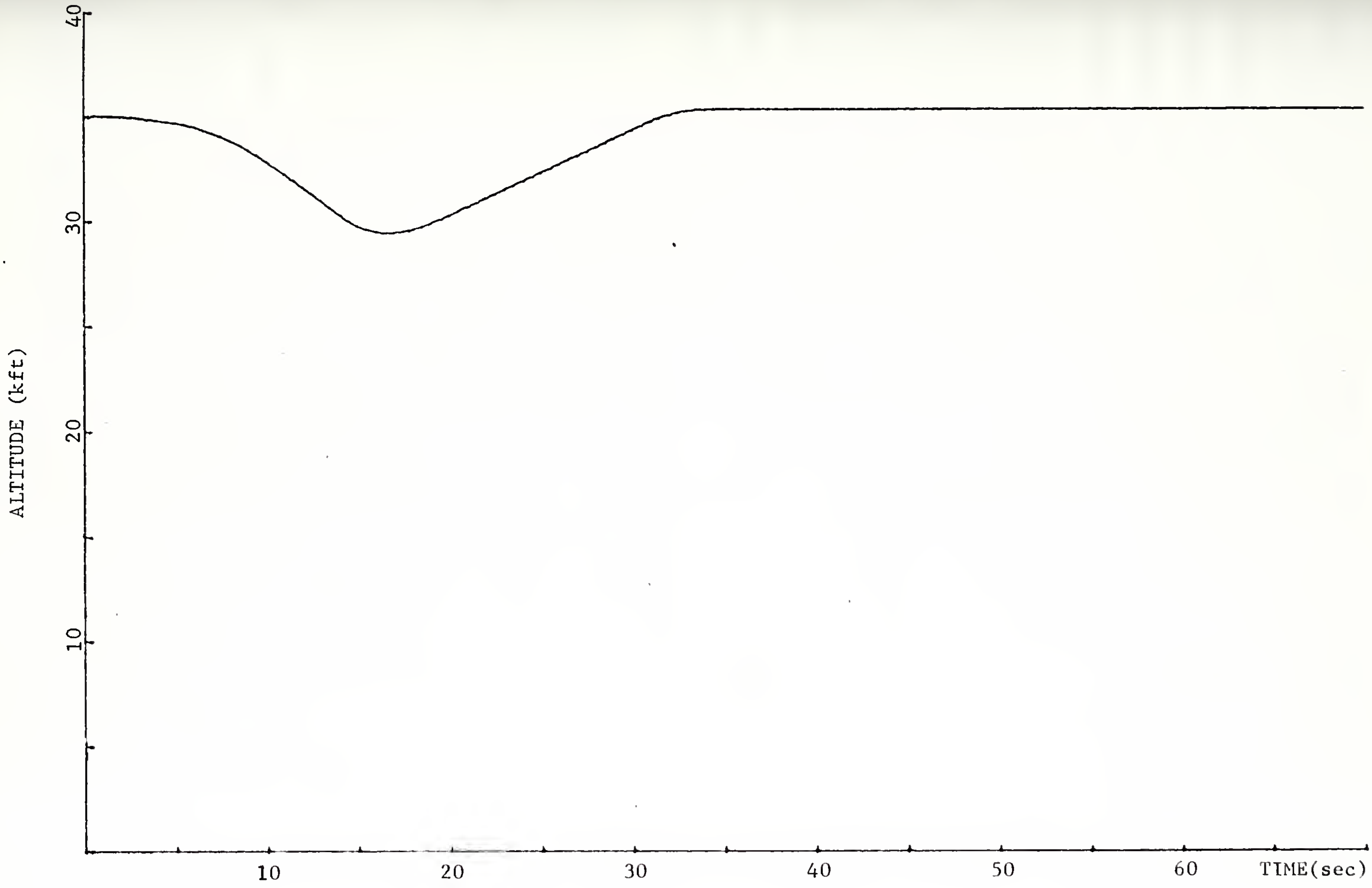
main deck. With this addition the program would now compile and link.

Now that the program would compile and link, attention was turned to getting a good simulation. To facilitate this process, two sample outputs were obtained from NWC. These outputs cover one missile flight which is broken down into a midcourse guidance and a terminal guidance simulation. Hereafter these will be referred to as midcourse baseline and terminal baseline, respectively. Using the initial conditions from the baseline models, it was hoped that the outputs could be duplicated.

A. MIDCOURSE GUIDANCE FLIGHT

The initial run, using the midcourse baseline inputs, revealed an overflow problem with the dynamic pressure (QD(508)). Using the traceback procedures outlined in the Users Manual from the W. R. Church Computer Center, the problem was confined to subroutine AIR. The problem turned out to be a translation error. The symbol PØ (Ø - zero) had translated to PØ in one place and PO in another. This error caused the program to use a value left in that memory location from a previous run to calculate the dynamic pressure. With this problem remedied, the program could progress a little farther. The next stumbling block appeared as a divide check. These errors were resolved by introducing patches that would bypass a statement that tried to divide by zero. Once bypassed, that quantity would be set equal to zero. This was the normal procedure of the computer, but it would stop the run after ten such errors. Having corrected all these errors, output was obtained which covered the desired seventy seconds of flight.

When the output was examined a major switching problem within subroutine A3 (missile propulsion module) was found. The midcourse baseline utilized a simplified ramjet model, but the output was not.



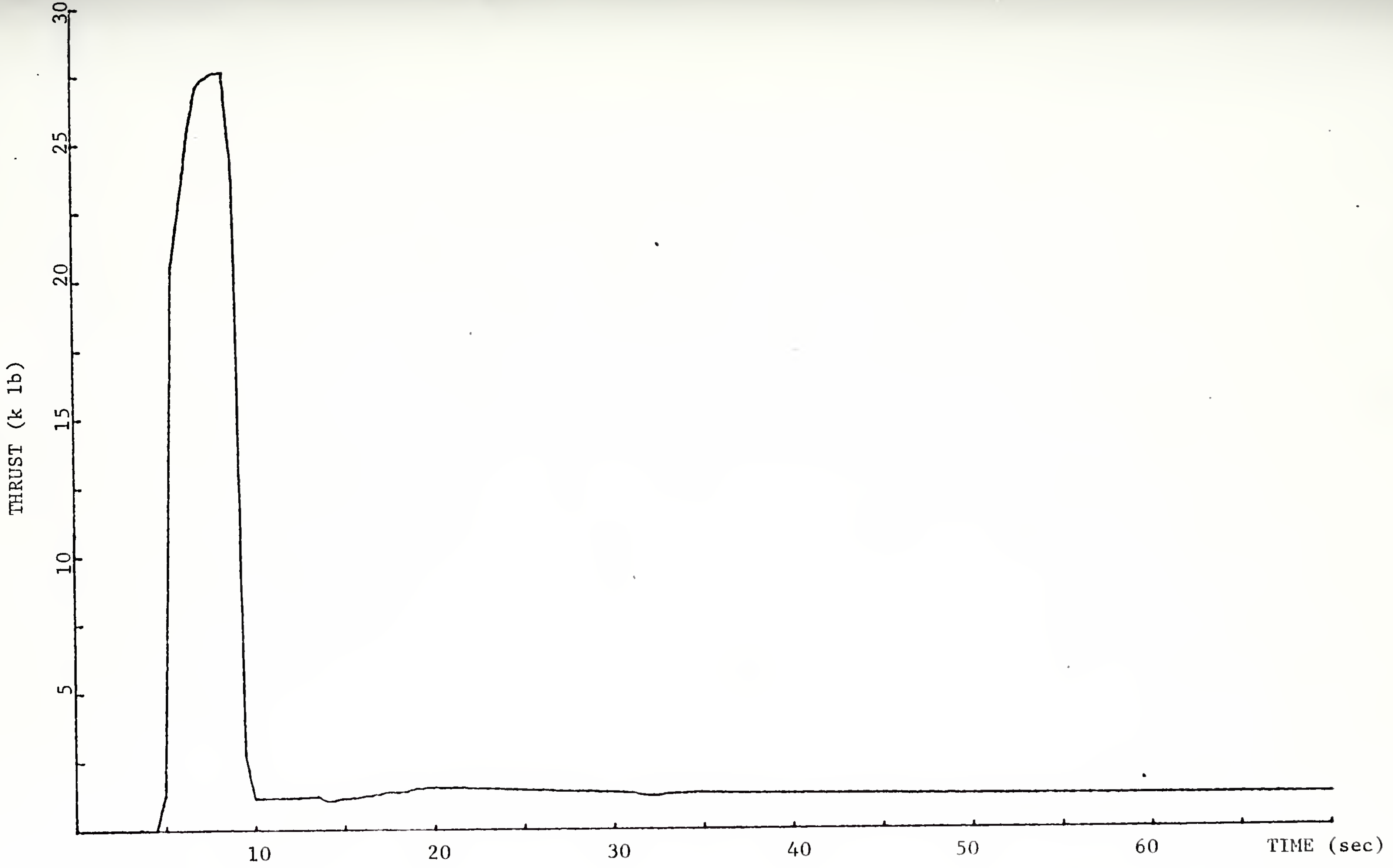
ALTITUDE VS. TIME (MIDCOURSE)

FIGURE 7

Rather than use RAMJET, the output disclosed that ENGINE had been used. The problem was in the logic statement, FLGRJ 0.0. The program was not making the desired switch to the simplified ramjet model. To remedy the problem, the data card FLGRJ(606) 1.0, was added to the input data deck. Another problem was discovered which occured between 14.0 and 14.5 seconds. During that time period the missile angle of attack (ALPHA (330)) exceeded ten degrees. When ALPHA exceeds this angle the engine is turned off. With the engine off, no thrust is produced causing the forward velocity (VXTP(286)) to decrease. This limitation was removed from the program. After eliminating these problems a flight trajectory, Figure 7, was obtained which closely resembled the output of the mid-course baseline. A random sampling of the outputed variables were compared for exactness. The differences noted were due primarily to computer round-off error.

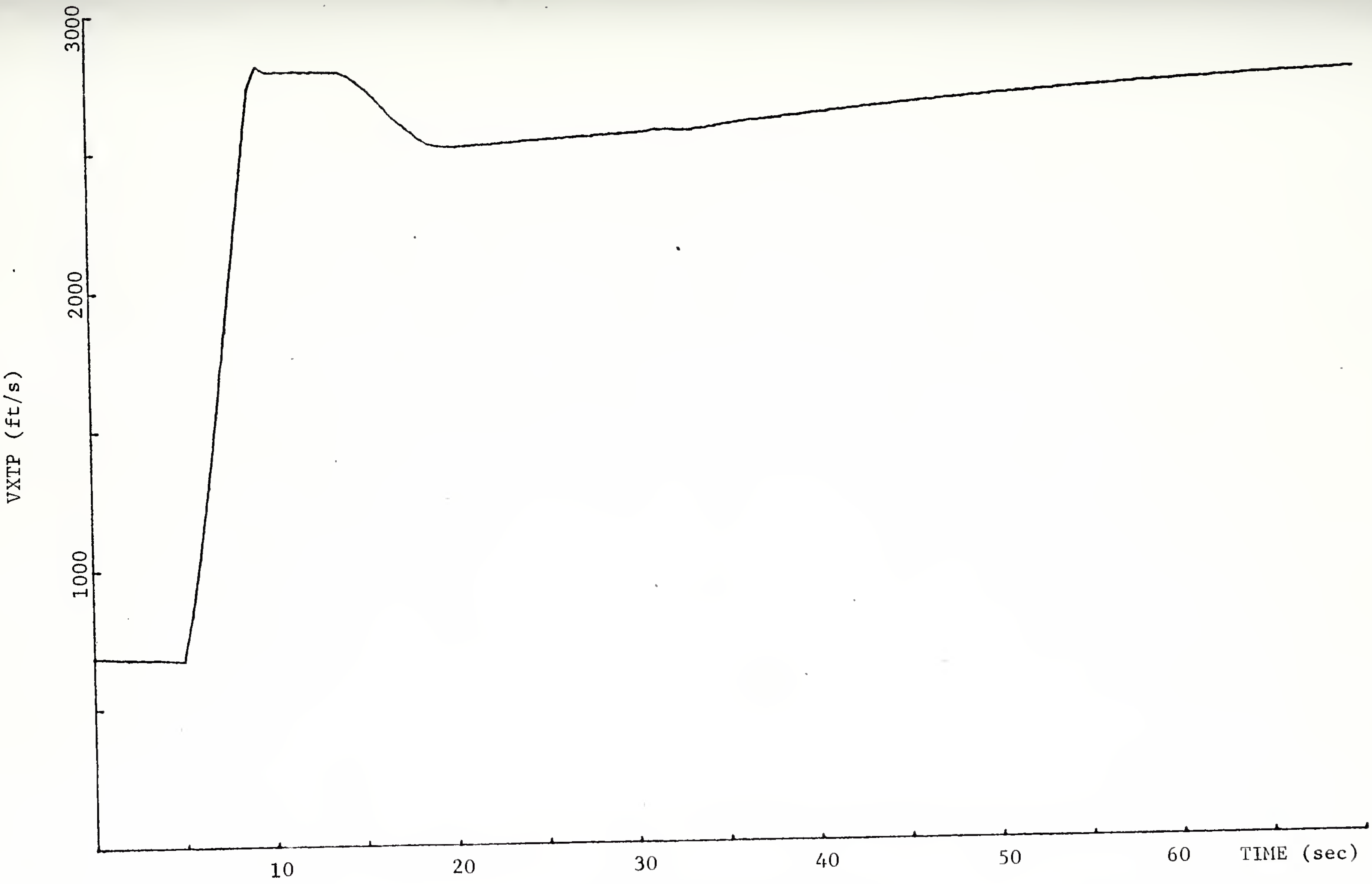
To further verify the accuracy of the two simulations, three parameter (TXBA(073), VXTP(286),and YTP(298))were chosen as representative values for the runs. To obtain a feel for the run, these parameters are plotted in Figures 8, 9, 10. Additionally, random time samples are tabulated in Tables I, II, III.

The thrust (TXBA(073)) plot, Figure 8, can easily be divided into four mission phases. During the separation phase (0.0 - 4.5 seconds) the thrust is zero. This is expected since neither of the engines have ignited. This is followed by a rapid increase in the thrust. The maximum thrust, 27800 lbs, happens during the boost phase (4.5 - 9.5 seconds). At 9.5 seconds the boost motor stops and the transition phase occurs for the next 0.3 seconds. During this time the thrust decreases rapidly since neither engine is on. Once the engine port covers are



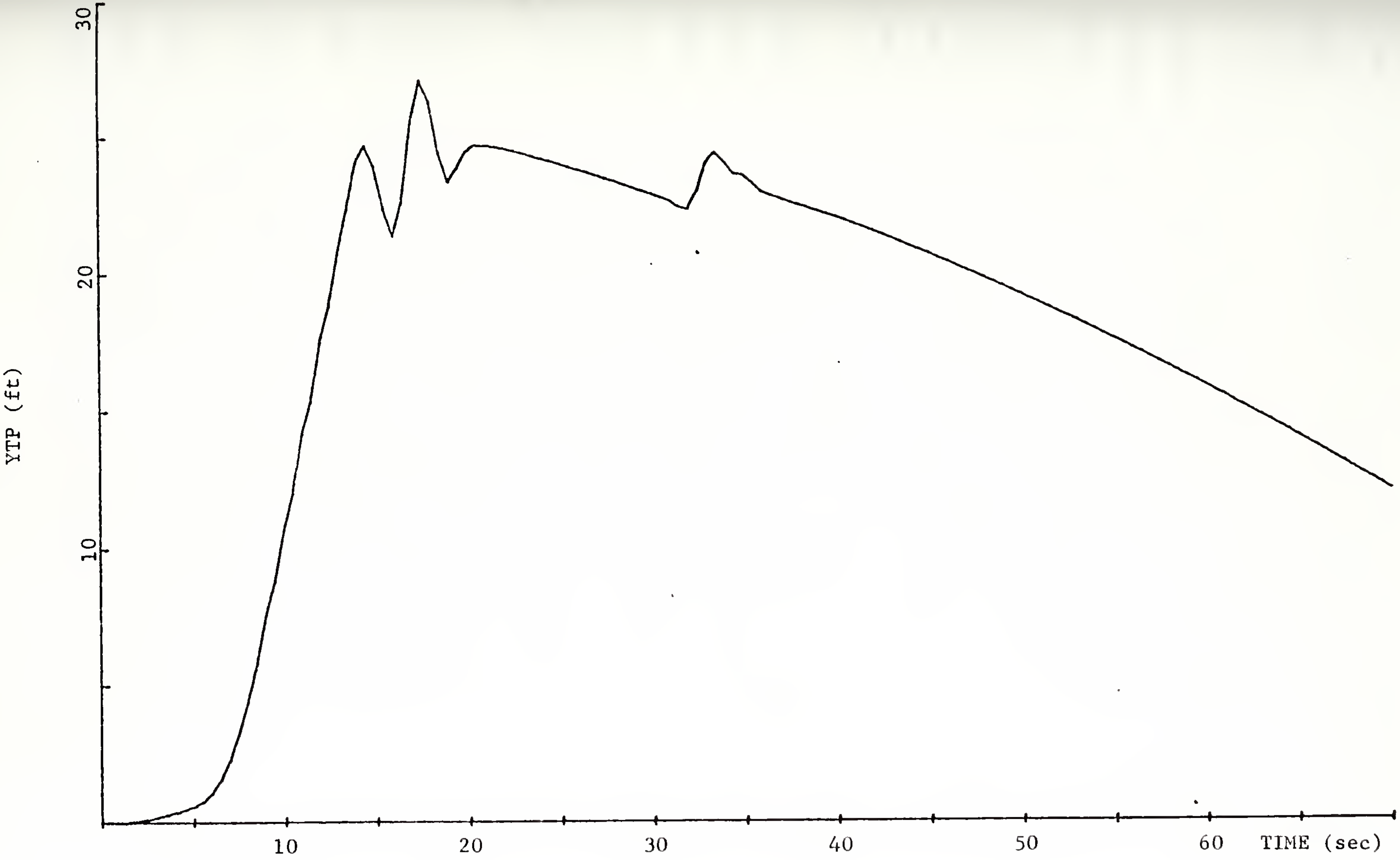
THRUST VS. TIME (MIDCOURSE)

FIGURE 8



VXTP VS. TIME (MIDCOURSE)

FIGURE 9



YTP VS. TIME (MIDCOURSE)

FIGURE 10

clear, the ramjet sustainer ignites. This action initiates the midcourse phase (9.8 - 70 seconds) and the thrust remains relatively constant at 1200 lbs.

The missile forward velocity (VXTP(286)) can be directly related to the thrust. During separation no thrust is produced, therefore the velocity is zero. As the missile is boosted to Mach two, the velocity increases and approaches its maximum value (2800 ft/s) just prior to boost engine shut-down. As the sustainer engine port covers clear, the velocity decreases slightly. Once the ramjet engine ignites the velocity profile is displayed in Figure 9 and it closely resembles that for the midcourse baseline.

The last parameter, y-displacement (YTP(298)), was included to demonstrate the accuracy of the guidance system Figure 10 shows that prior to attaining the cruise altitude, the missile wanders off track. Once the guidance system is activated, it makes the necessary corrections to return the missile to the planned flight path. Table III shows that the y-displacement corresponds to the baseline case and at the conclusion of the run the off-track error is down to 12.03 feet.

All the information obtained from the new run was checked against the midcourse baseline. The results showed that the two simulations are within acceptable limits. With this milestone completed, the program checkout could proceed to the terminal guidance flight.

B. TERMINAL GUIDANCE FLIGHT

To checkout the terminal guidance portion of the MOD6DF program, the initial conditions from the terminal baseline were used. This required changing about a dozen input cards in the midcourse input data deck. The first run attempted turned out successful. This was due to the

TIME	0.0	7.5	10.0	20.0	25.5	30.0	40.0	50.0	60.0	70.0
BASELINE	0.0	27395	1140.6	1403.0	1377.4	1281.0	1211.3	1178.0	1148.1	1124.8
NEW	0.0	27391	1138.9	1514.3	1418.4	1314.3	1249.9	1207.0	1175.5	1149.7

TXBA (073) COMPARISON (MIDCOURSE)

TABLE I

TIME	0.0	7.5	10.0	20.0	25.0	30.0	40.0	50.0	60.0	70.0
BASELINE	681.99	1858.3	2790.2	2606.7	2604.9	2613.4	2652.4	2705.0	2743.8	2771.5
NEW	681.99	1851.7	2786.3	2506.4	2525.9	2544.5	2605.0	2665.5	2710.8	2743.9

VXTP (286) COMPARISON (MIDCOURSE)

TABLE II

TIME	0.0	7.5	10.0	20.0	25.0	30.0	40.0	50.0	60.0	70.0
BASELINE	-.5E-5	3.46	11.37	27.21	25.92	24.34	20.45	16.93	13.24	9.39
NEW	-.5E-5	3.19	10.68	24.43	23.93	22.82	21.96	19.14	15.81	12.03

YTP (298) COMPARISON (MIDCOURSE)

TABLE III

TIME	0	5.0	10.0	12.6	15.0	17.6	20.0	22.6	25.0	TF
BASELINE	1141.9	1131.0	1077.8	1170.9	1309.4	1501.1	1730.0	2245.3	2565.8	2691.3
NEW	1141.6	1134.8	1099.4	1212.8	1359.3	1561.7	1800.0	2305.9	2584.3	3273.6

TXBA (073) COMPARISON (TERMINAL)

TABLE IV

TIME	0.0	5.0	10.0	12.6	15.0	17.6	20.0	22.6	25.0	TF
BASELINE	2750.0	2764.2	2654.6	2471.4	2225.7	1854.5	1391.4	1376.9	1413.1	1425.05
NEW	2750.0	2761.5	2631.5	2438.7	2192.1	1828.2	1389.3	1366.7	1406.1	1465.2

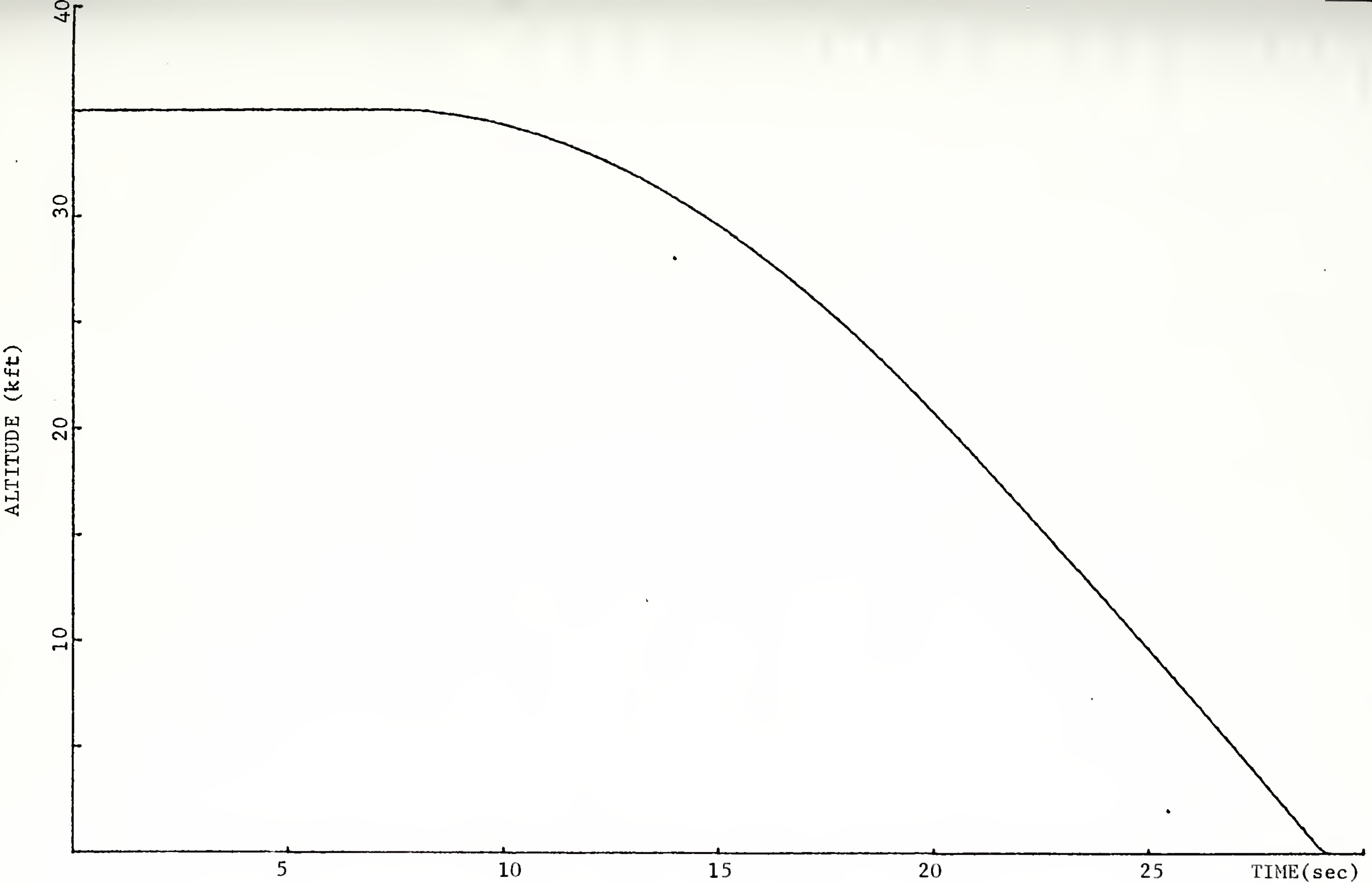
VXTP (286) COMPARISON (TERMINAL)

TABLE V

TIME	0.0	5.0	10.0	12.6	15.0	17.6	20.0	22.6	25.0	TF
BASELINE	0.0	0.0	-. 4E-6	-.5E-6	.7E-6	.9E-6	.1E-5	.2E-6	.1E-6	.1E-6
NEW	0.0	-. 0074	.019	-1.38	-.095	-.868	-1.77	.071	-.151	-.05

YTP (298) COMPARISON (TERMINAL)

TAVLE VI



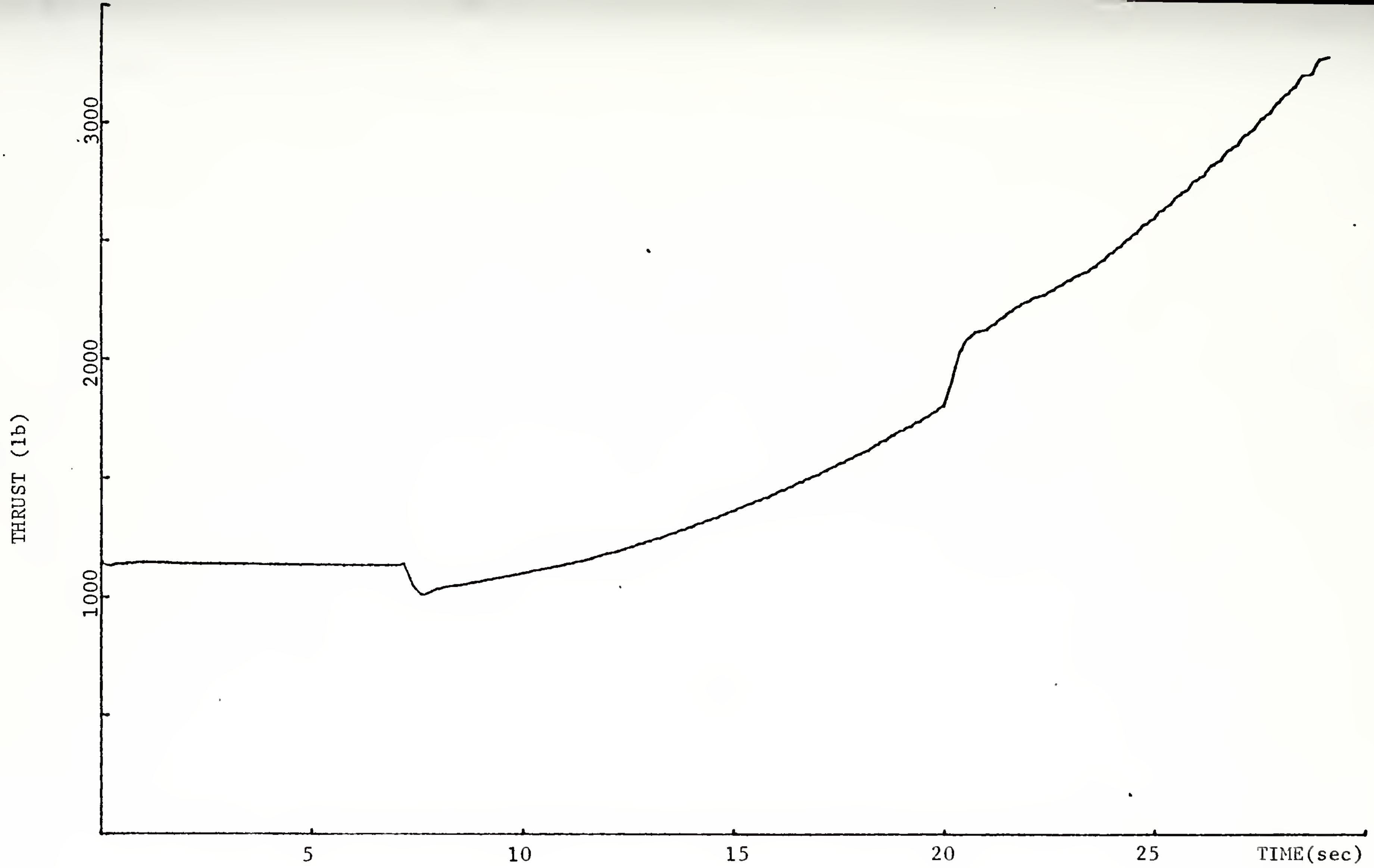
ALTITUDE VS.' TIME (TERMINAL)

FIGURE 11

elimination of all the errors during the midcourse checkout. The resulting flight trajectory, Figure 11, is a very good illustration of the desired profile. To check the accuracy of the simulation, the same three parameters were chosen. Tables IV and V show that this run is almost identical to the terminal baseline. The difference is primarily due to computer round-off error. Figures 12 and 13 show the overall flight performance of the thrust and forward velocity, respectively.

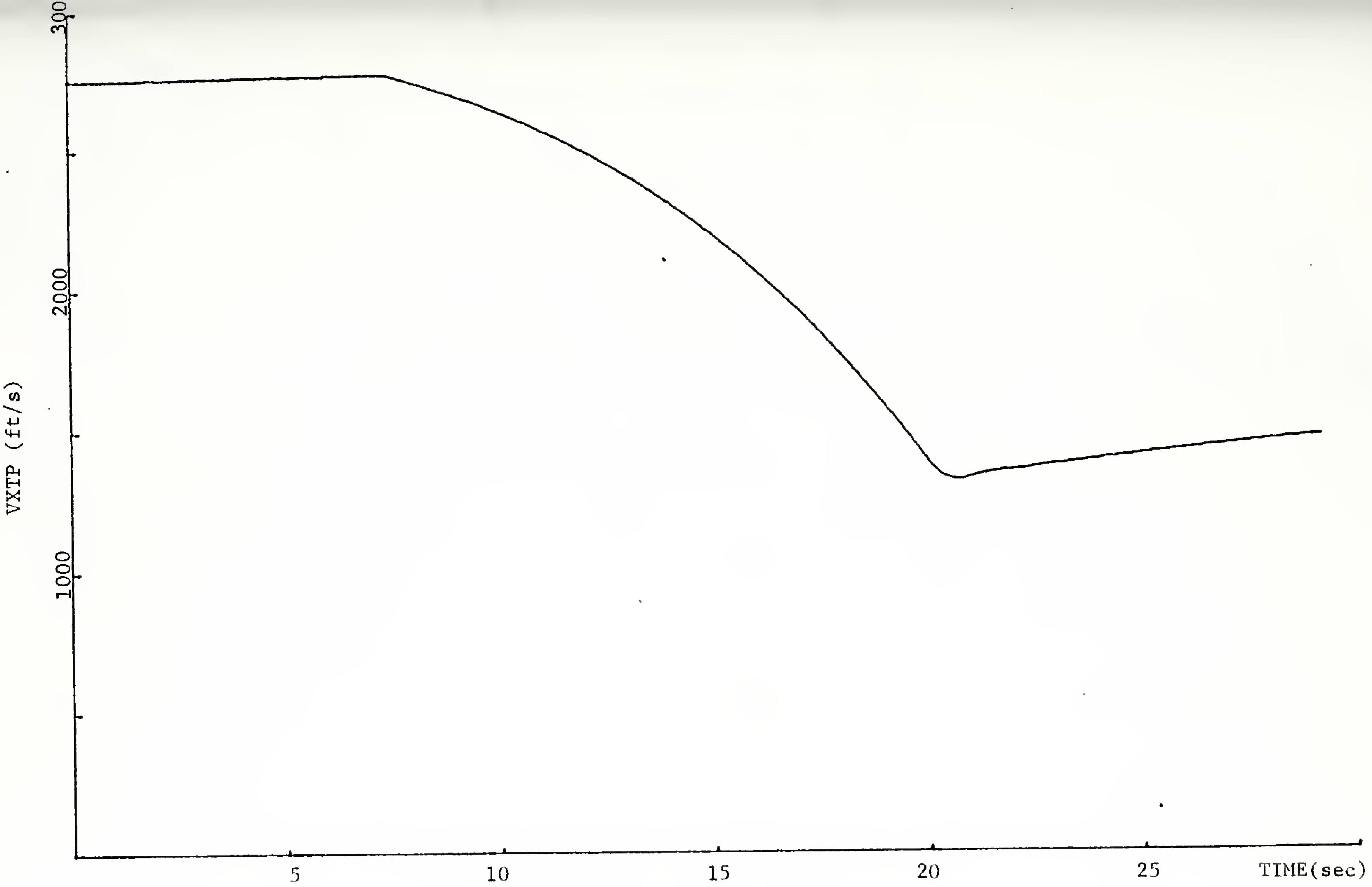
For this simulation, the y-displacement (YTP(298)) does not compare favorably with the terminal baseline. Figure 14 shows that between ten and twenty seconds in the flight, YTP develops rapid oscillations. By examining Table VI, it is noted that during this interval the two simulations differ the most. No reason for this discrepancy could be found. These oscillations do effect the flight by increasing the time of flight from 25.825 to 29.09 seconds and by increasing the miss distance. The imposed time constraints force this problem to be overlooked and to direct attention to the accuracy of the impact. Since the impact is within 0.5 feet of the target location, it is concluded that the terminal guidance simulation works properly.

With both segments of the MOD6DF computer program working correctly, thoughts could now turn towards the actual experimental runs. The results of these runs are discussed in the next section.



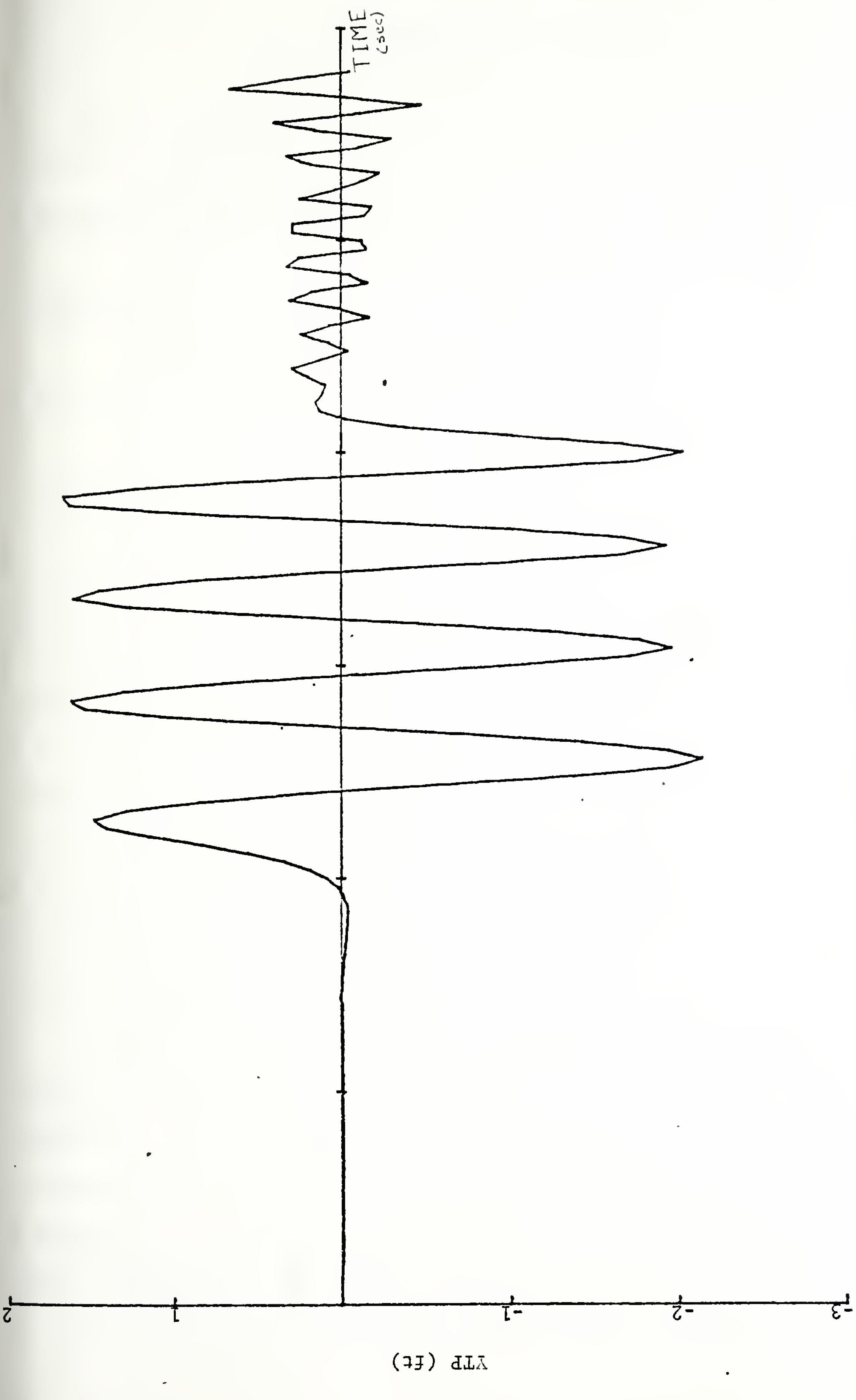
THRUST VS. TIME (TERMINAL)

FIGURE 12



VXTP VS. TIME (TERMINAL)

FIGURE 13



YTP VS. TIME (TERMINAL)

FIGURE 14

V. TERMINAL FLIGHT DISTURBANCES

With the checkout of the MOD6DF computer program completed, many ideas were discussed concerning alterations to the simulations. The three modifications decided upon were:

* examine target miss distance when changes were made to the initial x-y-z conditions,

* examine the terminal flight profile, range, and miss distance when the cruise altitude was reduced to approximate a sea skimming mode,

* examine target miss distance when random noise is applied to the missile homing seeker.

To understand the changes and results, one must be familiar with the frame of reference. The origin of the reference frame travels from the launch platform to the target location at the cruise altitude. This is called the tangent plane reference system. Displacements in the x-direction (XTP(290)) are measured from the launch platform in the direction of the target. Y-displacements (YTP(298)) are measured left or right of the ideal flight path, in the tangent plane. Any vertical displacement (ZTP(306)) is measured normal to the ideal flight path, with down being the positive direction. Using this frame of reference the information in Table VII is easier to understand.

The first modifications demonstrate the effect of changing YTP. YTP was increased until a result was reached that was unsatisfactory. From the results in Table VIII, the maximum value of YTP was determined to be 1800 feet. This conclusion corresponds with the results in reference 13. Since the missile is symmetric, it was also concluded that moving YTP either right or left would give the same results.

The fifth run simulated a drop in the missile's altitude. ZTP was

RUN	XTP	YTP	ZTP
BASELINE	1735552.5	0.0	0.0
1	173552.5	1000.0	0.0
2	173552.5	1500.0	0.0
3	173552.5	1800.0	0.0
4	173552.5	2000.0	0.0
5	173552.5	0.0	2000.0

INITIAL CONDITIONS

TABLE VII

RUN	XTP	YTP	ZTP	IMPACT TIME
BASELINE	234999.56	-.0506363	34999.34	28.825
1	234999.81	.1259258	34999.836	29.108
2	235000.19	.11479032	35000.32	29.124
3	235000.25	.15263242	35000.391	29.134
4	269802.0	2000.0	19705.00	35.0
5	234999.63	.45691	35000.426	30.365

IMPACT RESULTS

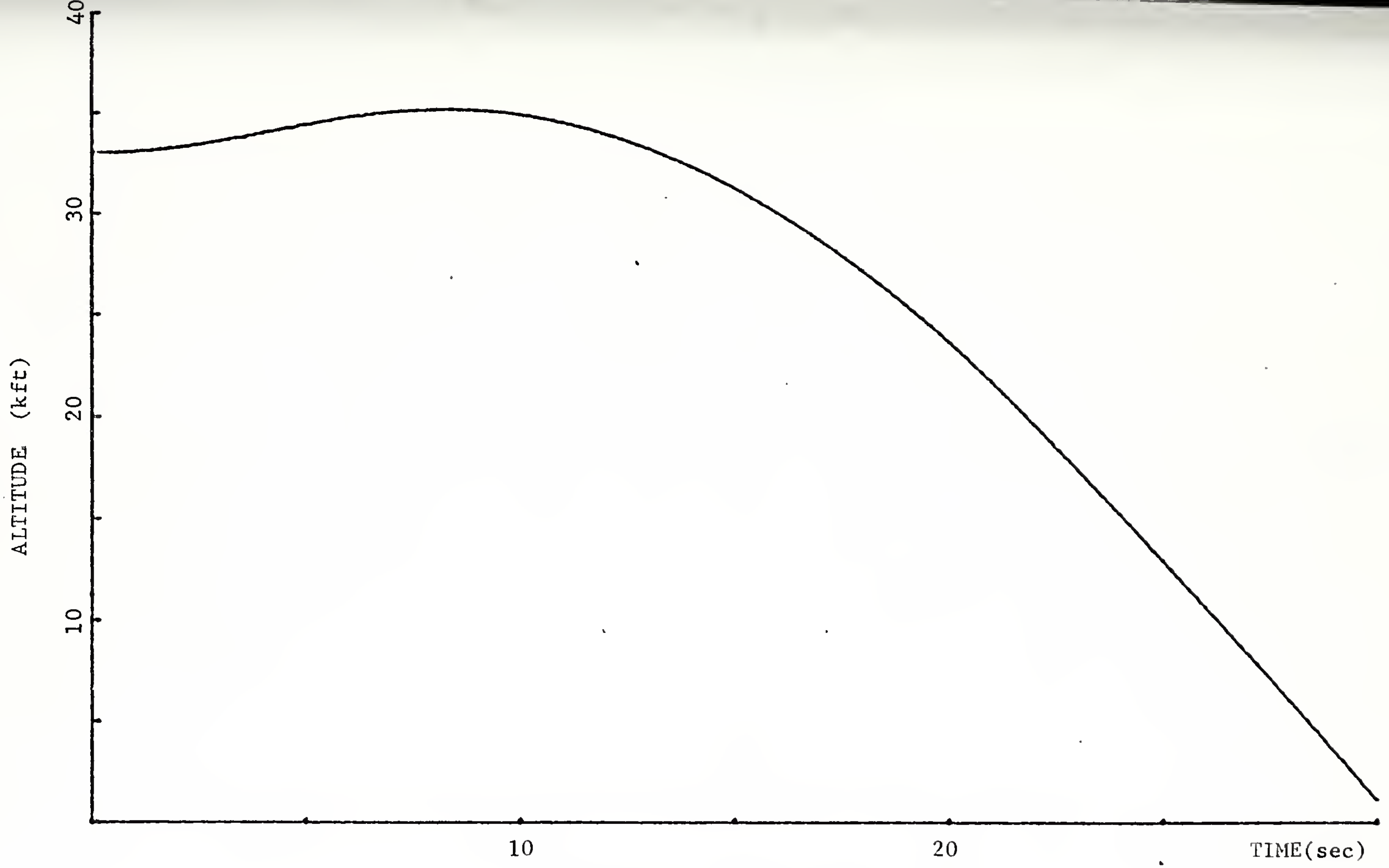
TABLE VIII

inputed as 2000.0 feet. As the simulation progressed, the missile developed the necessary commands to climb and regain the desired cruise altitude (Figure 15). It then commenced its terminal dive. The target was detected, acquired, and impact followed. This initial condition modification produced the largest miss distance (0.457 ft.).

Figure 16 was presented to show the relative locations of the miss distances for each change. Table VIII reveals that up until 1800 feet, changes to YTP created very little variation in the miss distance. It should be noted that the larger the displacement became, the greater the time until impact. The increase in time was necessary to allow the missile to acquire the target and then compute the required acuator commands to impact the target. This concluded the investigation of the effects of initial displacement error on target miss distance.

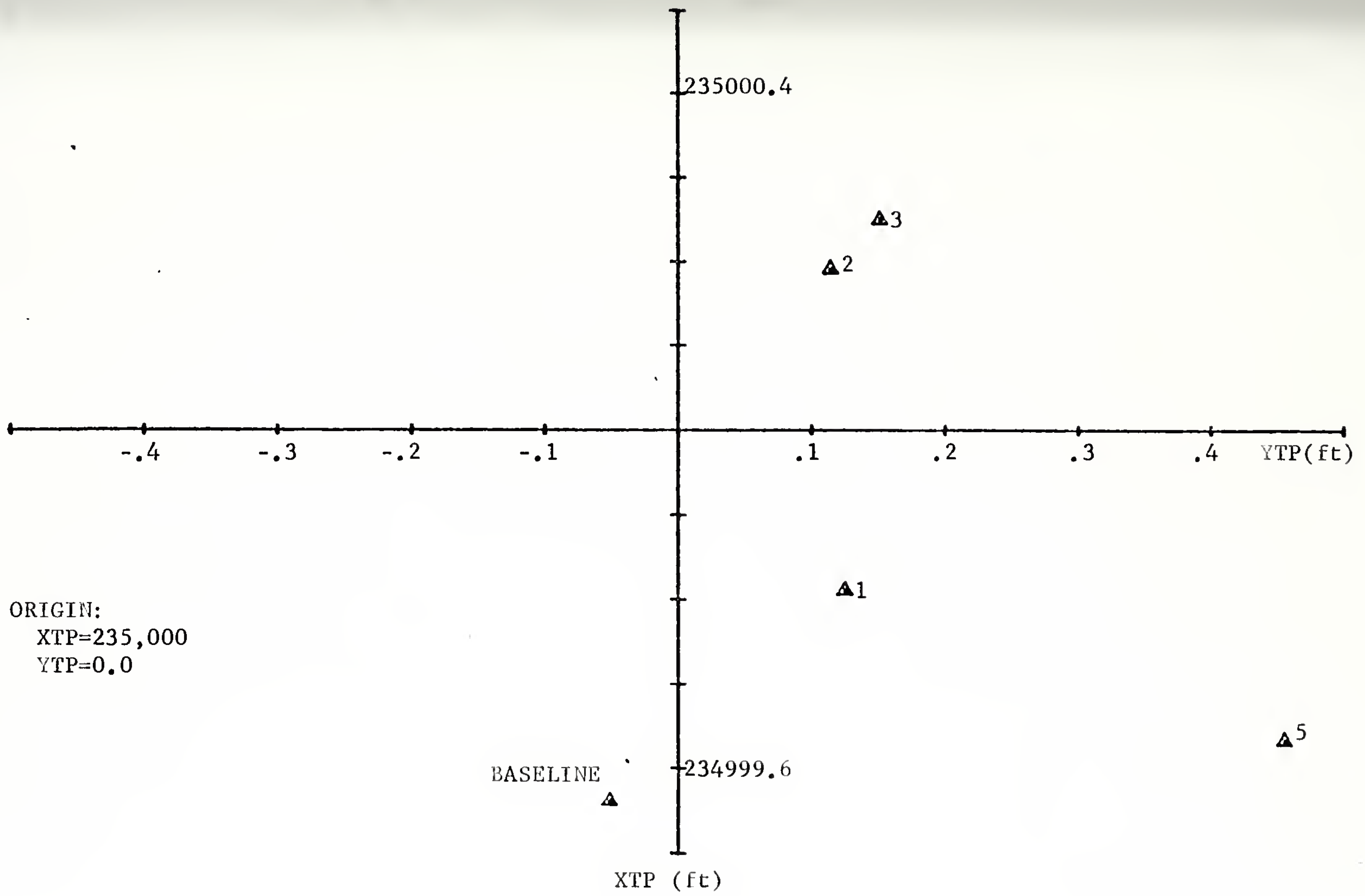
The idea behind changing the cruise altitude was to try and simulate a sea skimming profile. RAMJET contains tables that allow for four cruise altitudes. Of these four altitudes, the lowest (500 ft) was chosen even though it is high for a sea-skimmer. To run this simulation only two input data card changes were required. HO(414) and HREF(501) had to be set equal to the desired altitude. The resultant flight path is shown in Figure 17.

The simulation produced an error-free output, but at first glance the results appeared unacceptable. Still trying to compare miss distances, the downrange distance (XTP) was fourd to be 197916 feet. Comparing this to the terminal baseline (234999) resulted in an extreme error. It was then realized that the missile must expend more fuel at this altitude to attain the same speed. Therefore, the results could be correct. As further verification of the correctness of the run, it was assumed that the missile weight at impact should be fairly equal. The



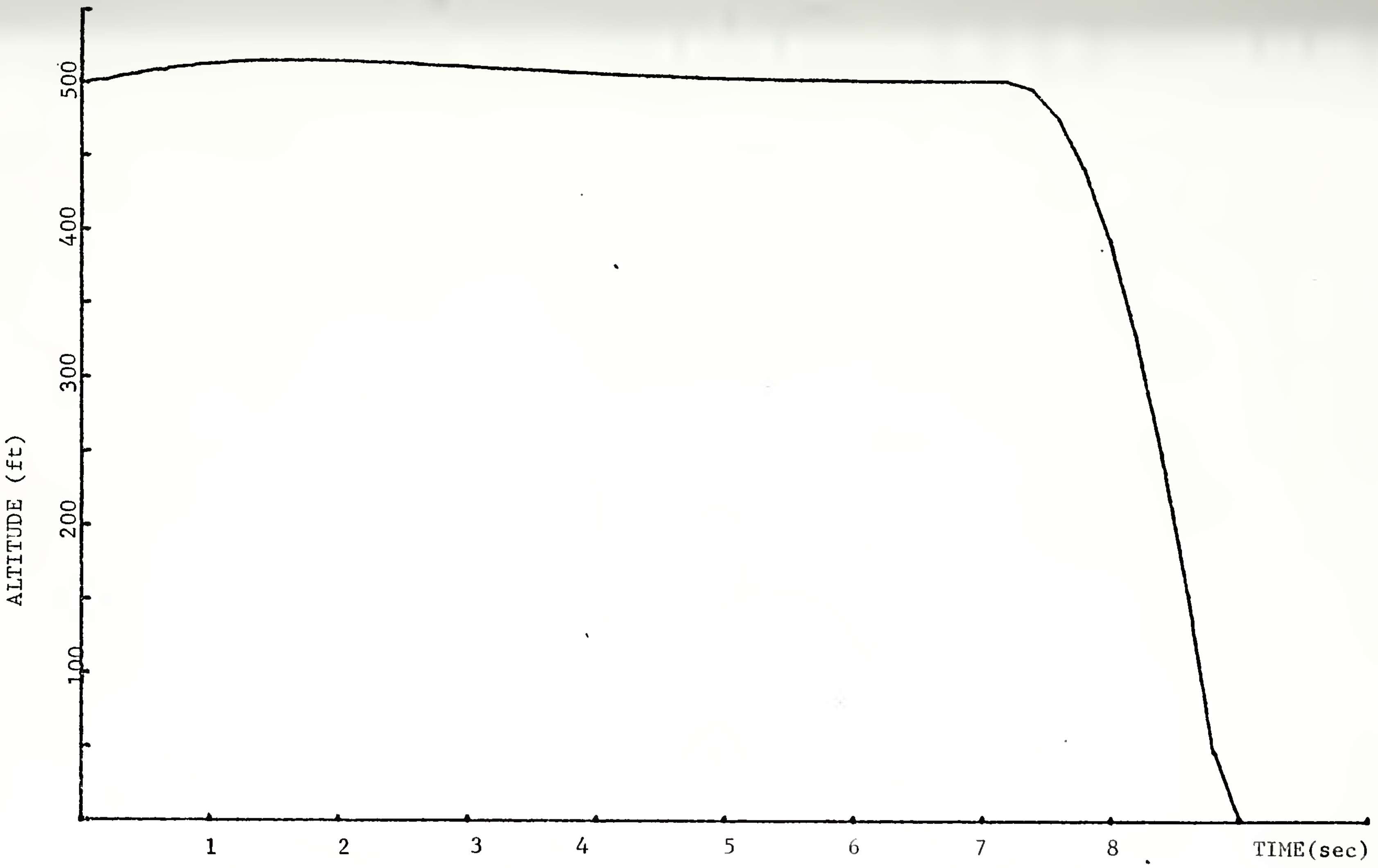
ALTITUDE VS. TIME (TERMINAL - ZTP)

FIGURE 15



IMPACT RESULTS

FIGURE 16



ALTITUDE VS. TIME (SEA-SKIMMER)

FIGURE 17

simulation impact weight was 1126.34 lbs while the terminal baseline weighed 1113.12 lbs. Since no conflicting information could be found in reference 12, it was concluded that this simulation was correct.

The final flight disturbance investigated was the addition of random noise to the missile homing seeker. This simulation proved to be unsuccessful due to invalid input format. The information describing the process is brief and difficult to understand. Further information from NWC China Lake is required to be able to successfully run simulations with random noise.

With the completion of these modifications, many unanswered problems and questions still exist. The two most critical problems concern the input of random noise generators and the missile exceeding the angle of attack limitation when using ENGINE for cruise propulsion. However, the simulations did show that the MOD6DF program runs correctly at alternate cruise altitudes and with initial displacement errors.

VI. CONCLUSION

The MOD6DF computer program from NWC China Lake was converted to operate on the IBM-360 computer at the Naval Postgraduate School. The program would only function properly when using the simplified ramjet model. When this model was not used, the missile angle of attack exceeded the maximum limit of ten degrees. This error caused the ramjet engine to flame out.

Target impact errors for the terminal guidance problem were investigated when the initial displacement was modified. These modiifications demonstrate the missile's accuracy when removed from the ideal flight path. The results also point out that if the target falls within the seeker search pattern, target impact will inevitably happen.

Random noise generation is possible with the MOD6DF program. However, more information discussing the parameters required to develop the noise is necessary. Additionally, sample noise inputs should be obtained that reflect the alteration to the noise subroutines.

This research involved the preliminary investigation of the MOD6DF program. The program has many possible areas, concerning guidance and control of tactical missiles, which could be developed for future study. These areas not only include the unresolved problems encountered during this research. Additionally, reference 14 and 15 contain many examples of possible advanced guidance concepts.

COMPUTER OUTPUT

```
1   INPT1                        0.0              0.0
1   CUPT2.3                      0.0              0.0
1   STGF2.3                      0.0              0.0
2   MODULE G1I.G1                0.0              0.0
2   MODULE G3I.G3                0.0              0.0
2   MODULE C5I.C5                0.0              0.0
2   MODULE S5I.S5                0.0              0.0
2   MODULE S2I.S2                0.0              0.0
2   MODULE S1I.S1                0.0              0.0
2   MODULE C2I.C2                0.0              0.0
2   MODULE C1I.C1                0.0              0.0
2   MODULE A4I.A4                0.0              0.0
2   MODULE A3I.A3                0.0              0.0
2   MODULE A2I.A2                0.0              0.0
2   MODULE A1I.A1                0.0              0.0
2   MODULE [illegible]                0.0              0.0
2   MODULE [illegible]                0.0              0.0
3   W                            [illegible]      0.1[illegible] 01
3     FLCSTF                     0.10[illegible] 01    0.0
3     S                          0.1[illegible]  01    0.0
3     CEAF                       0.1[illegible]  01    0.0
3   CGI                          0.9264499[illegible] 01  0.100000000E 01
3     EPSTH                      0.0              0.0
3     NUTH                       0.0              0.0
3   A                     201    0.6514497[illegible] 01  0.100000000E 01
3   B                     203    0.4[illegible] 03      0.100000000E 01
3   CC                    206    0.465258320 03   0.100000000E 01
3     TSA                 210    0.0              0.0
3     ELP                 211    0.99999937E-03   0.0
3     ULP                 212    0.99999964E-01   0.0
3     P                   214    0.0              0.100000000E 01
3     ELQ                 215    0.99999993E-03   0.0
3     ULQ                 216    0.99999964E-01   0.0
3     Q                   218    0.0              0.100000000E 01
3     ELR                 219    0.99999937E-03   0.0
3     ULR                 220    0.99999964E-01   0.0
3     R                          0.0              0.100000000E 01
3      ELA11                     0.99999937E-03   0.0
3      ULA11                     0.99999964E-01   0.0
3      ELA12                     0.99999937E-03   0.0
3      ULA12                     0.99999964E-01   0.0
3      ELA13                     0.99999993E-03   0.0
3      ULA13                     0.99999964E-01   0.0
3      ELA21                     0.99999993E-03   0.0
3      ULA21                     0.99999964E-01   0.0
3      ELA22                     0.99999993E-03   0.0
3      ULA22                     0.99999964E-01   0.0
3      ELA23                     0.99999993E-03   0.0
3      ULA23                     0.99999954E-01   0.0
3      ELA31                     0.99999993E-03   0.0
3      ULA31                     0.99999964E-01   0.0
3      ELA32                     0.99999993E-03   0.0
3      ULA32                     0.99999964E-01   0.0
3      ELA33                     0.99999953E-03   0.0
3      ULA33                     0.99999964E-01   0.0
3      CG189                     0.9489999[illegible] 01  0.0
3      AKS                       0.20[illegible] 02     0.0
3      OMGYD              260    0.0              0.100000000E 01
3      ELOMGY             262    0.99999937E-03   0.0
3        EUOMGY           264    0.99999964E-01   0.0
3      OMGY               265    0.0              0.100000000E 01
3      OMGZD              266    0.0              0.100000000E 01
3      ELOMGZ             267    0.99999993E-03   0.0
3      EUOMGZ             268    0.99999964E-01   0.0
3      OMGZ               269    0.0              0.100000000E 01
3      THTSD              270    0.0              0.100000000E 01
3      ELTHTS             271    0.99999937E-03   0.0
3      EUTHTS             272    0.99999964E-01   0.0
3      THTS               273    0.0              0.100000000E 01
3      PSISD              274    0.0              0.100000000E 01
3      ELPSIS             275    0.99999993E-03   0.0
3      EUPSIS             276    0.99999964E-01   0.0
3      PSIS               277    0.0              0.100000000E 01
3      AG                 282    0.21719973E 02   0.0
3      ELVX               284    0.99999937E-03   0.0
3      EUVX               285    0.99999964E-01   0.0
3     VX                  286    0.275[illegible] 04   0.100000000E 01
3      ELX    S           288    0.99999937E-03   0.0
3      EUX    S           289    0.99999964E-01   0.0
3     X                   290    0.1[illegible] 06     0.100000000E 01
3      ELVY    S          292    0.99999937E-03   0.0
3      EUVY    S          293    0.99999964E-01   0.0
3      VY                 294    0.0              0.100000000E 01
```

```
3     RLG3            1719       0.99999964E-01 0.0
3     D3              1720       0.0            0.10000000E 01
3     RLD4            1722       0.99999993E-13 0.0
3     FLD4            1723       0.99999964E-01 0.0
3     D4              1724       0.0            0.10000000E 01
3     FLZ1            1726       0.99999993E-13 0.0
3     RLZ1            1727       0.99999964E-01 0.0
3     Z1              1728       0.0            0.10000000E 01
3     FLY1            1730       0.99999993E-03 0.0
3     RLY1            1731       0.99999964E-01 0.0
3     Y1              1732       0.0            0.10000000E 01
3      OMEGAS         1733       0.14000000E 03 0.0
3      DAMP S         1734       0.69999999E 00 0.0
3    OMEGA FIN        1735       0.10000000E 13 0.0
3     DAMP FIN        1736       0.69999999E 00 0.0
3     MAX FIN         1740       0.34906586E 00 0.0
3     OMEGA F         1737       0.35000000E 01 0.0
3    CPP              2665       0.15999999E 00 0.0
3    ROLLG            2901       0.0            0.0
3    PITCHG           2902       0.30999998E-01 0.0
3     YAWG            2903       0.0            0.0
3    STEP             2905       0.11000000E 02 0.0
3     DCG             2909       0.60000000E 01 0.0
3     HMIN            2911       0.49999990E-02 0.0
3    HMAX             2912       0.20000000E-01 0.0
3    EFF(1)           2913       0.49999990E-02 0.10000000E 01
3     PUNCH           3400       0.0            0.0
4         THRUST        73       0.0            0.0
4         WEIGHT        36       0.0            0.0
4         X(TP)        297       0.0            0.0
4         VX(TP)       366       0.0            0.0
4         AY(SA)       711       0.0            0.0
4         G            216       0.0            0.0
4         ALT          517       0.0            0.0
4         Y(TP)        236       0.0            0.0
4         VY(TP)       254       0.0            0.0
4         AZM         1644       0.0            0.0
4         H            220       0.0            0.0
4         VELOCITY     556       0.0            0.0
4         Z(TP)        305       0.0            0.0
4         VZ(TP)       312       0.0            0.0
4         AZ(SA)       712       0.0            0.0
4         P            312       0.0            0.0
4         PITCH        331       0.0            0.0
4         ALPHA(DEG)   333       0.0            0.0
4         AAZG        1636       0.0            0.0
4         BETA(DEG)    331       0.0            0.0
4         ANYG        1643       0.0            0.0
4         ANGLE        533       0.0            0.0
4       DELTA Q(DEG)   332       0.0            0.0
4       DELTA R(DEG)   333       0.0            0.0
4       DELTA P(DEG)   334       0.0            0.0
4       THRUST MARGIN  605       0.0            0.0
4         DYN P        551       0.0            0.0
4         YAW          532       0.0            0.0
4         ROLL         533       0.0            0.0
4         GAMMAV       527       0.0            0.0
6                        0       0.0            0.0
&ACNT
ENG= 0.43553397    , 0.54999999    , 0.04999999    , 1.52749997    , 0.65215911    , 1.11420014    , 0.0    , 0.99999957    ,
  1.0000000     , 2.0000000     , 0.50000000    , 1.1999998     , 0.35999999E-11, 14.630420    , 1.5750000    , 0.0    ;
 0.0            ; 0.0           ; 0.0           ; 0.0           ; 0.0           ; 0.0           , 1.0    ; 1.0    ;
 0.0            . 0.0           , 0.0           ; 0.0           , 0.0           . 0.0           , [illegible]    0,      1,
            2.            0.           2.            0.             0.            1.             0.         0.          0.        0.       0.
            0.            0
&END
       *** US 1962 STANDARD ATMOSPHERE
       *** ALTITUDE FROM 0 TO    30480. METERS
```

```
 TIME              THRUST            WEIGHT            X(TP)             VX(TP)            AY(FT)
                   G                 ALT               Y(TP)             VY(TP)            AZ
                   F                 VELOCITY          Z(TP)             VZ(TP)            AZ(FT)
                   P                 PITCH             ALPHA(DEG)        N/Z               BETA(DEG)
                   ANYC              ANACE             DELTA G(DEG)      DELTA E(DEG)      DELTA F(DEG)
                   INLET MARGIN      DYN P             YAW               ROLL              CANAV


0.49999950E-02    0.11416790E 04    0.11525549E 04    0.17356625E 06    0.27[illegible] 04    0.0
                  0.25043402E-01    0.35000000E 05    0.0               0.0               -0.49554611E 02
                  0.0               0.27590186E 04    0.49968915E-04    0.[illegible]-01  -0.38664548E 02
                  0.0               0.30764110E-01    0.17630310E 01    0.[illegible] 00  0.0
                  0.0               0.28195744E 01    0.66758852E-01    0.0               0.0
                  0.0               0.19290527E 02    0.0               0.0               -0.66045795E-05

0.20999992E 00    0.11322258E 04    0.11522550E 04    0.17413020E 06    0.2[illegible] 04    0.10[illegible] 00
                  -0.52350126E-02   0.35011273E 05    0.91678184E-03    0.[illegible]-01  -0.[illegible] 02
                  -0.80484524E-03   0.27502271E 04    -0.27663858E 01   -0.[illegible] 01  -0.[illegible] 02
                  -0.77179372E-02   0.42367656E-01    0.23562231E 01    0.[illegible] 00  0.11157024E-[illegible]
                  -0.91046725E-04   0.28195587E 01    0.65386245E 01    -0.[illegible]-02 0.1[illegible]14E-01
                  0.0               0.19292421E 02    -0.56245452E-04   -0.[illegible]-03 0.1[illegible]27E-0[illegible]

0.40499991E 00    0.11408408E 04    0.11521667E 04    0.17366625E 06    0.[illegible] 04    -0.153[illegible]
                  -0.53[illegible]-01   0.35011231E 05    0.27361391E-02    -0.[illegible]-02  -0.62576[illegible] 02
                  0.32734742E-03    0.27500394E 04    -0.13016148E 01   -0.[illegible] 01  -0.47[illegible]
                  0.78949891E-02    0.35059491E-01    0.18716938E 01    0.[illegible] 01  0.62[illegible]-0[illegible]
                  -0.18129953E-03   0.28196037E 01    0.51715565E 01    -0.[illegible]-01 -0.76[illegible]4C-[illegible]
                  0.0               0.19285764E 02    -0.13072976E-03   -0.[illegible]-03 0.2[illegible]37950E-[illegible]

0.60499984E 00    0.11444492E 04    0.11519714E 04    0.17523666E 06    0.[illegible] 04    -0.[illegible]-01
                  -0.39283269E-01   0.35002779E 05    -0.22953226E-02   -0.517[illegible]-01  -0.33059707E [illegible]
                  0.42343186E-03    0.27504169E 04    -0.27724276E 01   -0.7[illegible] 01  -0.31756[illegible]
                  -0.62761131E-04   0.35817899E-01    0.13198285E 01    0.[illegible] 00  0.1[illegible]47[illegible]-0[illegible]
                  0.17035036E-03    0.28200034E 01    0.43705608E 01    -0.[illegible]-02 -0.7[illegible]5607[illegible]
                  0.0               0.19263511E 02    -0.35915157E-04   0.[illegible]-04  0.[illegible]34O[illegible]

0.80499983E 00    0.11462571E 04    0.11517761E 04    0.17576644E 06    0.[illegible] 04    0.47[illegible]731E-01
                  -0.20372772E-01   0.35004246E 05    -0.46110637E-02   -0.[illegible]-01  -0.2[illegible]18269 02
                  0.18810772E-03    0.27509515E 04    -0.42470367E 01   -0.[illegible] 01  -0.[illegible]43F16 [illegible]
                  -0.10566069E-03   0.19836720E-01    0.69310791E 00    0.[illegible] 00  -0.17910091E-0[illegible]
                  0.44583622E-03    0.28205980E 01    0.39568267E 01    0.[illegible]-02  0.13977359E-[illegible]
                  0.0               0.19300650E 02    0.24477573E-04    0.[illegible]-04  0.[illegible]37152E-02
```

COMPUTER PROGRAM

```
C
C
C         THIS IS THE MAIN MCD6DF PROGRAM
C
      COMMON C(3415), TEMPS(1500)                                       MCD60010
      EQUIVALENCE (C(3315),N)                                           MCD60020
      EQUIVALENCE (C(2911),HMIN)                                        MCD60030
      EQUIVALENCE (C(2912),HMAX)                                        MCD60040
      EQUIVALENCE (C(2913),DER(1))                                      MCD60050
      EQUIVALENCE (C(3014),VAR(1))                                      MCD60060
      EQUIVALENCE (C(3115),EL(1))                                       MCD60070
      EQUIVALENCE (C(3215),EU(1))                                       MCD60100
      EQUIVALENCE (C(3316),IPL(1))                                      MCD60110
      EQUIVALENCE (C( 932),T      )                                     MCD60120
      EQUIVALENCE (C(2904),KSTEP), (C(2905),STEP)                       MCD60130
      EQUIVALENCE(C(2907),LSTEP)                                        MCD60140
      DIMENSION IPL(100)                                                MCD60150
      DIMENSION DER(101)                                                MCD60160
      DIMENSION VAR(101)                                                MCD60170
      DIMENSION  EL(100)                                                MCD60200
      DIMENSION  EU(100)                                                MCD60210
      M=N
      N=M
 1000 CALL ZERO                                                         MCD60220
 1001 CALL CINPT1                                                       MCD60230
      LSTEP = STEP                                                      MCD60240
 1002 CALL  SUEL1                                                       MCD60250
 1003 CALL  AUXI                                                        MCD60260
 1004 CALL  SUBL2                                                       MCD60270
 1005 DO 60 I = 2,N                                                     MCD60300
      J = IPL(I-1)                                                      MCD60310
      EL(I-1) = C(J+1)                                                  MCD60320
      EU(I-1) = C(J+2)                                                  MCD60330
      VAR(I) = C(J+3)                                                   MCD60340
   60 DER(1) = C(J)                                                     MCD60350
      VAR(1) = T                                                        MCD60360
 1006 CALL   AUXSUB                                                     MCD60370
 1007 CALL AMRK                                                         MCD60400
 1008 DO 50 I = 2, N                                                    MCD60410
      J = IPL(I-1)                                                      MCD60420
   50 C(J+3) = VAR(I)                                                   MCD60430
      T = VAR(1)                                                        MCD60440
 1009 CALL  SUEL3                                                       MCD60450
C     IF (KSTEP .EQ. 1) GO TO 1007                                      MCD60460
      IF (KSTEP - 1) 70,1007,70                                         MCD60470
   70 CALL PROCES                                                       MCD60500
      CALL RESET                                                        MCD60510
      GO TO (1000,1001,1002,1003,1004,1005,1006,1007,1008,1009,1010),   MCD60520
```

```
    1 LSTEP                                                             MCD60530
 1010 CALL EXIT                                                         MCD60540
      STOP                                                              MCD60545
      END                                                               MCD60550
C
C
C
      SUBROUTINE ZERO
C
      COMMON C(3415)
      DO 1 KLEAR = 1, 4915
    1 C(KLEAR) = 0.0
      RETURN
      END
C
C
      SUBROUTINE OINPT1                                                 CINP0030
C
C     BASIC INPUT SUBROUTINE OINPT1                                     CINP0010
C     SUBROUTINE OINPT1 IS THE BASIC INPUT SUBROUTINE                   CINP0020
C
      DIMENSION LISTNO(50), VALUE(50)                                   CINP0230
      DIMENSION SUBNO(99),IR(2),VR(2)                                   CINP0240
      DIMENSION RNDMNO(50)                                              CINP0250
      DIMENSION ALPHA(4),ONAME1(50),ONAME2(50),ONAME3(50),OUTNO(50)
      DIMENSION MODNO(99)                                               CINP0300
      DIMENSION STATNO (100)                                            CINP0040
      COMMON C(3415)                                                    CINP0310
      REAL MODNO                                                        CINP0320
      INTEGER OUTNO                                                     CINP0330
      INTEGER RNDMNO                                                    CINP0340
      INTEGER STATNO                                                    CINP0050
      EQUIVALENCE (C(2442),LOSTAT)
      EQUIVALENCE (C(2200),STATNO(1)),(C(2441),NOSTAT)
      EQUIVALENCE  (C(2801),NOSUB),(C(2802),SUBNO(1)),(C(2663),IR(1)),
     1 (C(2665),VR(1))
      EQUIVALENCE   (C(2701),NCMOD)                                     CINP0110
      EQUIVALENCE   (C(2661),NOOUT)                                     CINP0120
      EQUIVALENCE ( C(2448),   NORNDM )                                 CINP0130
      EQUIVALENCE  (C(2300),NOLIST),(C(2301),LISTNO(1)),(C(2351),
     1 VALUE(1))
      EQUIVALENCE  (C(2500) , OUTNO(1))
      EQUIVALENCE  (C(2550) , ONAME1(1))
      EQUIVALENCE  (C(2600) , ONAME2(1))
      EQUIVALENCE (C(2150) , ONAME3(1))
      EQUIVALENCE  (C(2450) , RNDMNO(1))
      EQUIVALENCE (C(2702),MODNO(1))                                    CINP0350
      JAR = 0
```

```
    1 READ(5,2) IR(1),ALPHA(1),ALPHA(2),ALPHA(3),ALPHA(4),IR(2),VR(1),
     1 VR(2)
      WRITE(6,2) IR(1),ALPHA(1),ALPHA(2),ALPHA(3),ALPHA(4),IR(2),VR(1),
     1 VR(2)
    2 FORMAT(I2,2X,4A4,I5,5X,2E15.8)
C     IF (IR(1) .NE. 0) GO TO 7                                         CINP0410
      IF (IR(1)) 7,18,7                                                 CINP0420
   18 I1 = IR(2)                                                        CINP0430
      REWIND I1                                                         CINP0440
      I2 = VR(1) - 1.                                                   CINP0450
      I3 = VR(2)                                                        CINP0460
      IF (I2) 11,15,14                                                  CINP0470
   14 DO 8 I = 1,I2                                                     CINP0500
    8 READ (I1,10) J,X                                                  CINP0510
   15 DO 9 I = 1,I3                                                     CINP0520
      READ (I1,2) J,X                                                   CINP0530
    9 C(J) = X                                                          CINP0540
   10 FORMAT (I5,E15.9)                                                 CINP0550
      GO TO 1                                                           CINP0560
   11 JAR = 1                                                           CINP0570
      GO TO 1                                                           CINP0600
C   7 IF (IR(1) .NE. 1) GO TO 3                                         CINP0610
    7 IF (IR(1) - 1) 3,19,3                                             CINP0620
   19 NOSUB = NOSUB + 1                                                 CINP0630
      SUBNO(NOSUB) = IR(2)                                              CINP0640
      GO TO 1                                                           CINP0650
C   3 IF (IR(1) .NE. 2) GO TO 4                                         CINP0660
    3 IF (IR(1) - 2) 4,20,4                                             CINP0670
   20 NOMOD = NOMOD + 1                                                 CINP0700
      MODNO(NOMOD) = IR(2)                                              CINP0710
      GO TO 1                                                           CINP0720
C   4 IF (IR(1) .NE. 3) GO TO 5                                         CINP0730
    4 IF (IR(1) - 3) 5,21,5                                             CINP0740
   21 L = IR(2)                                                         CINP0750
      C(L) = VR(1)                                                      CINP0760
C     IF (JAR .EQ. 1) WRITE (I1,10)L,VR(1)                              CINP0770
      IF (JAR - 1) 23,22,23                                             CINP1000
   22 WRITE (I1,10)L,VR(1)                                              CINP1010
C     IF (VR(2) .EQ. 0.) GO TO 1                                        CINP1020
   23 IF (VR(2)) 24,1,24                                                CINP1030
   24 NOLIST = NOLIST + 1                                               CINP1040
      LISTNO(NOLIST) = L                                                CINP1050
      VALUE(NOLIST) = VR(1)                                             CINP1060
      GO TO 1                                                           CINP1070
C   5 IF (IR(1) .NE. 4) GO TO 6                                         CINP1100
    5 IF (IR(1) - 4) 6,25,6                                             CINP1110
   25 NOCUT = NOCUT +1                                                  CINP1120
      CNAME1(NOCUT) = ALPHA(2)
```

```
      CNAME2(NOCUT) = ALPHA(3)
      CNAME3(NOCUT) = ALPHA(4)
      CUTNO(NOCUT) = IR(2)                                              CINP1150
      GO TO 1                                                           CINP1160
C     6 IF (IR(1) .NE. 5) GO TO 16                                      CINP1170
    6 IF (IR(1) - 5) 16,26,16                                           CINP1200
C     IF (VR(1) .EQ. 0.) GO TO 17                                       CINP1210
   26 IF (VR(1)) 27,17,27                                               CINP1220
   27 LOSTAT = LOSTAT + 1                                               CINP1230
   17 NOSTAT = NOSTAT + 1                                               CINP1240
      STATNO(NOSTAT) = IR(2)                                            CINP1250
      GO TO 1                                                           CINP1260
   16 NORNDM=0
C     IF (IR(2).EQ.0) RETURN
      IF (IR(2)) 29,28,29
   28 RETURN                                                            CINP1310
   29 N = IR(2)                                                         CINP1320
      DO 12 I = 1, N                                                    CINP1330
      READ (5,13) J,Y,ZSTART,SIGNO,BETA
      WRITE (6,13) J,Y,ZSTART,SIGNO,BETA
   13 FORMAT (I5,F5.0,3E15.9)
      NORNDM = NORNDM + 1                                               CINP1370
      RNDMNO(I) = J                                                     CINP1400
      C(J) = Y                                                          CINP1410
      C(J+1)=ZSTART
      C(J+3) = SIGNO                                                    CINP1440
   12 C(J+4) = BETA                                                     CINP1450
      RETURN                                                            CINP1460
      END                                                               CINP1470
C
C
C
      SUBROUTINE   SUBL1                                                SUBL0010
C
      COMMON C(3415)                                                    SUBL0020
      DIMENSION   SUBNO(99)                                             SUBL0050
      EQUIVALENCE (C(2801),NOSUB)                                       SUBL0030
      EQUIVALENCE  (C(2802),SUBNO(1))
      DO 1 I = 1, NOSUB                                                 SUBL0060
      J = SUBNO(I)                                                      SUBL0070
      GO TO ( 1, 2, 3, 4, 5, 6, 7, 8, 9 ), J                            SUBL0100
    2 CALL INFT1                                                        SUBL0110
      GO TO 1                                                           SUBL0120
    3 CALL CUPT1                                                        SUBL0130
      GO TO 1                                                           SUBL0140
    4 CALL SIGE1                                                        SUBL0150
      GO TO 1                                                           SUBL0160
    5 CALL CNTR1                                                        SUBL0170
```

```
      GO TO 1                                                           SUBL0200
    6 CALL RNDM1                                                        SUBL0210
      GO TO 1                                                           SUBL0220
    7 CALL AUXA1                                                        SUBL0230
      GO TO 1                                                           SUBL0240
    8 CALL AUXB1                                                        SUBL0250
      GO TO 1                                                           SUBL0260
    9 CALL AUXC1                                                        SUBL0270
    1 CONTINUE                                                          SUBL0300
      RETURN                                                            SUBL0310
       END                                                              SUBL0320
C
C
C
      SUBROUTINE   SUBL2                                                SUBL0010
C
      DIMENSION  SUBNO(99)                                              SUBL0050
      COMMON C(3415)                                                    SUBL0020
      EQUIVALENCE (C(2801),NOSUB)                                       SUBL0030
      EQUIVALENCE  (C(2802),SUBNO(1))
      DO 1 I = 1, NOSUB                                                 SUBL0060
      J = SUBNO(I)                                                      SUBL0070
      GO TO ( 1, 2, 3, 4, 5, 6, 7, 8, 9 ), J                            SUBL0100
    2 CALL INPT2                                                        SUBL0110
      GO TO 1                                                           SUBL0120
    3 CALL OUPT2                                                        SUBL0130
      GO TO 1                                                           SUBL0140
    4 CALL STGE2                                                        SUBL0150
      GO TO 1                                                           SUBL0160
    5 CALL CNTR2                                                        SUBL0170
      GO TO 1                                                           SUBL0200
    6 CALL RNDM2                                                        SUBL0210
      GO TO 1                                                           SUBL0220
    7 CALL AUXA2                                                        SUBL0230
      GO TO 1                                                           SUBL0240
    8 CALL AUXB2                                                        SUBL0250
      GO TO 1                                                           SUBL0260
    9 CALL AUXC2                                                        SUBL0270
    1 CONTINUE                                                          SUBL0300
      RETURN                                                            SUBL0310
       END                                                              SUBL0320
C
C
C
      SUBROUTINE   SUBL3                                                SUBL0010
C
      DIMENSION  SUBNO(99)                                              SUBL0050
      COMMON C(3415)                                                    SUBL0020
```

```
      EQUIVALENCE (C(2801),NOSUB)                                         SUBL0030
      EQUIVALENCE  (C(2802),SUBNO(1))
      DO 1 I = 1, NOSUB                                                   SUBL0060
      J = SUBNO(I)                                                        SUBL0070
      GO TO ( 1, 2, 3, 4, 5, 6, 7, 8, 9 ), J                              SUBL0100
    2 CALL INPT3                                                          SUBL0110
      GO TO 1                                                             SUBL0120
    3 CALL CLFT3                                                          SUBL0130
      GO TO 1                                                             SUBL0140
    4 CALL STGE3                                                          SUBL0150
      GO TO 1                                                             SUBL0160
    5 CALL CNTR3                                                          SUBL0170
      GO TO 1                                                             SUBL0200
    6 CALL RNDM3                                                          SUBL0210
      GO TO 1                                                             SUBL0220
    7 CALL AUXA3                                                          SUBL0230
      GO TO 1                                                             SUBL0240

    8 CALL AUXB3                                                          SUBL0250
      GO TO 1                                                             SUBL0260
    9 CALL AUXC3                                                          SUBL0270
    1 CONTINUE                                                            SUBL0300
      RETURN                                                              SUBL0310
       END                                                                SUBL0320
C
C
C
      SUBROUTINE AUXI                                                     AUXI0010
C
      DIMENSION  MODNO(99)                                                AUXI0060
      COMMON C(3415)                                                      AUXI0020
      REAL MODNO                                                          AUXI0070
      EQUIVALENCE (C(2701), NCMOD)                                        AUXI0030
      EQUIVALENCE (C(2702),MODNO(1))
      EQUIVALENCE (C(2659), CNCE)
      EQUIVALENCE (C(3315),N)                                             AUXI0050
      N = 1                                                               AUXI0100
      CNCE = 0
      DO 1 I=1,NCMOD                                                      AUXI0110
      L = MODNO(I)                                                        AUXI0120
      GO TO (1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23AUXI0130
     1      ,24,25,26,27,28,29,30,31,32,33,34,35,36,37),L                 AUXI0140
    2 CALL A1I                                                            AUXI0150
      GO TO 1                                                             AUXI0160
    3 CALL A2I                                                            AUXI0170
      GO TO 1                                                             AUXI0200
    4 CALL A3I                                                            AUXI0210
      GO TO 1                                                             AUXI0220
```

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    5 CALL A4I                                                          ALXI0230
      GO TO 1                                                           ALXI0240
    6 CALL A5I                                                          ALXI0250
      GO TO 1                                                           ALXI0260
    7 CALL C1I                                                          ALXI0270
      GO TO 1                                                           ALXI0300
    8 CALL C2I                                                          ALXI0310
      GO TO 1                                                           ALXI0320
    9 CALL C3I                                                          ALXI0330
      GO TO 1                                                           ALXI0340
   10 CALL C4I                                                          ALXI0350
      GO TO 1                                                           ALXI0360
   11 CALL C5I                                                          ALXI0370
      GO TO 1                                                           ALXI0400
   12 CALL C6I                                                          ALXI0410
      GO TO 1                                                           ALXI0420
   13 CALL C7I                                                          ALXI0430
      GO TO 1                                                           ALXI0440
   14 CALL C8I                                                          ALXI0450
      GO TO 1                                                           ALXI0460
   15 CALL C9I                                                          ALXI0470
      GO TO 1                                                           ALXI0500
   16 CALL C10I                                                         ALXI0510
      GO TO 1                                                           ALXI0520
   17 CALL D1I                                                          ALXI0530
      GO TO 1                                                           ALXI0540
   18 CALL D2I                                                          ALXI0550
      GO TO 1                                                           ALXI0560
   19 CALL D3I                                                          ALXI0570
      GO TO 1                                                           ALXI0600
   20 CALL D4I                                                          ALXI0610
      GO TO 1                                                           ALXI0620
   21 CALL D5I                                                          ALXI0630
      GO TO 1                                                           ALXI0640
   22 CALL G1I                                                          ALXI0650
      GO TO 1                                                           ALXI0660
   23 CALL G2I                                                          ALXI0670
      GO TO 1                                                           ALXI0700
   24 CALL G3I                                                          ALXI0710
      GO TO 1                                                           ALXI0720
   25 CALL G4I                                                          ALXI0730
      GO TO 1                                                           ALXI0740
   26 CALL G5I                                                          ALXI0750
      GO TO 1                                                           ALXI0760
   27 CALL G6I                                                          ALXI0770
      GO TO 1                                                           ALXI1000
   28 CALL S1I                                                          ALXI1010
      GO TO 1                                                           ALXI1020
```

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   29 CALL S2I                                                          AUXI1030
      GO TO 1                                                           AUXI1040
   30 CALL S3I                                                          AUXI1050
      GO TO 1                                                           AUXI1060
   31 CALL S4I                                                          AUXI1070
      GO TO 1                                                           AUXI1100
   32 CALL S5I                                                          AUXI1110
      GO TO 1                                                           AUXI1120
   33 CALL S6I                                                          AUXI1130
      GO TO 1                                                           AUXI1140
   34 CALL S7I                                                          AUXI1150
      GO TO 1                                                           AUXI1160
   35 CALL S8I                                                          AUXI1170
      GO TO 1                                                           AUXI1200
   36 CALL S9I                                                          AUXI1210
      GO TO 1                                                           AUXI1220
   37 CALL S10I                                                         AUXI1230
    1 CONTINUE                                                          AUXI1240
      RETURN                                                            AUXI1250
      END                                                               AUXI1260
C
C
C
      SUBROUTINE AUXSUB                                                 AUXS0010
C
      DIMENSION DER(101)                                                AUXS0120
      DIMENSION VAR(101)                                                AUXS0130
      DIMENSION IPL(100)                                                AUXS0140
      DIMENSION  MODNO(99)                                              AUXS0150
      COMMON C(3415)                                                    AUXS0020
      REAL MODNO                                                        AUXS0160
      EQUIVALENCE (C(2701), NOMOD)                                      AUXS0030
      EQUIVALENCE (C(2702),MODNO(1))
      EQUIVALENCE (C(3316),IPL(1))
      EQUIVALENCE (C(3014),VAR(1))
      EQUIVALENCE (C(2913),DER(1))
      EQUIVALENCE (C( 932),T)                                           AUXS0100
      EQUIVALENCE (C(3315),N)                                           AUXS0110
      DO 50 I = 2, N                                                    AUXS0170
      J = IPL(I-1)                                                      AUXS0200
   50 C(J+3) = VAR(I)                                                   AUXS0210
      T = VAR(1)                                                        AUXS0220
      DO 1 I=1,NOMOD                                                    AUXS0230
      L = MODNO(I)                                                      AUXS0240
      GO TO (1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,  AUXS0250
     123,24,25,26,27,28,29,30,31,32,33,34,35,36,37),L                   AUXS0260
    2 CALL A1                                                           AUXS0270
      GO TO 1                                                           AUXS0300
```

```
    3 CALL A2                                                           ALXS0310
      GO TO 1                                                           ALXS0320
    4 CALL A3                                                           ALXS0330
      GO TO 1                                                           ALXS0340
    5 CALL A4                                                           ALXS0350
      GO TO 1                                                           ALXS0360
    6 CALL A5                                                           ALXS0370
      GO TO 1                                                           ALXS0400
    7 CALL C1                                                           ALXS0410
      GO TO 1                                                           ALXS0420
    8 CALL C2                                                           ALXS0430
      GO TO 1                                                           ALXS0440
    9 CALL C3                                                           ALXS0450
      GO TO 1                                                           ALXS0460
   10 CALL C4                                                           ALXS0470
      GO TO 1                                                           ALXS0500
   11 CALL C5                                                           ALXS0510
      GO TO 1                                                           ALXS0520
   12 CALL C6                                                           ALXS0530
      GO TO 1                                                           ALXS0540
   13 CALL C7                                                           ALXS0550
      GO TO 1                                                           ALXS0560
   14 CALL C8                                                           ALXS0570
      GO TO 1                                                           ALXS0600
   15 CALL C9                                                           ALXS0610
      GO TO 1                                                           ALXS0620
   16 CALL C10                                                          ALXS0630
      GO TO 1                                                           ALXS0640
   17 CALL D1                                                           ALXS0650
      GO TO 1                                                           ALXS0660
   18 CALL D2                                                           ALXS0670
      GO TO 1                                                           ALXS0700
   19 CALL D3                                                           ALXS0710
      GO TO 1                                                           ALXS0720
   20 CALL D4                                                           ALXS0730
      GO TO 1                                                           ALXS0740
   21 CALL D5                                                           ALXS0750
      GO TO 1                                                           ALXS0760
   22 CALL G1                                                           ALXS0770
      GO TO 1                                                           ALXS1000
   23 CALL G2                                                           ALXS1010
      GO TO 1                                                           ALXS1020
   24 CALL G3                                                           ALXS1030
      GO TO 1                                                           ALXS1040
   25 CALL G4                                                           ALXS1050
      GO TO 1                                                           ALXS1060
   26 CALL G5                                                           ALXS1070
      GO TO 1                                                           ALXS1100
```

```
   27 CALL G6                                                           ALXS1110
      GO TO 1                                                           ALXS1120
   28 CALL S1                                                           ALXS1130
      GO TO 1                                                           ALXS1140
   29 CALL S2                                                           ALXS1150
      GO TO 1                                                           ALXS1160
   30 CALL S3                                                           ALXS1170
      GO TO 1                                                           ALXS1200
   31 CALL S4                                                           ALXS1210
      GO TO 1                                                           ALXS1220
   32 CALL S5                                                           ALXS1230
      GO TO 1                                                           ALXS1240
   33 CALL S6                                                           ALXS1250
      GO TO 1                                                           ALXS1260
   34 CALL S7                                                           ALXS1270
      GO TO 1                                                           ALXS1300
   35 CALL S8                                                           ALXS1310
      GO TO 1                                                           ALXS1320
   36 CALL S9                                                           ALXS1330
      GO TO 1                                                           ALXS1340
   37 CALL S10                                                          ALXS1350
    1 CONTINUE                                                          ALXS1360
      DO 60 I = 2, N                                                    ALXS1370
      J = IFL(I-1)                                                      ALXS1400
   60 DER(I) = C(J)                                                     ALXS1410
      RETURN                                                            ALXS1420
      END                                                               ALXS1430
C
C
C
      SUBROUTINE AMRK                                                   AMRK0010
C                                                                       AMRK0020
C          DOUBLE PRECISION VERSION. SAVES FUNCTION VALUES AND          AMRK0030
C              THE INDEPENDANT VARIABLE IN FULL D.P.                    AMRK0040
C                                                                       AMRK0050
      DIMENSION V(1),D(1),EU(1),FL(1)                                   AMRK0170
      DOUBLE PRECISION P1,P2,P3,P4,C2,C3,C4                             AMRK0210
      DOUBLE PRECISION T(1500), TME, DELT
      COMMON C(3416) ,T
      EQUIVALENCE  (C(3014),V(1))
      EQUIVALENCE  (C(2913) , D(1)    )
      EQUIVALENCE  (C(3215) , EU(1)   )
      EQUIVALENCE  (C(3115) , FL(1)   )
      EQUIVALENCE (C(2659), ONCE)
      EQUIVALENCE (C(3315) , NI   )                                     AMRK0110
      EQUIVALENCE (C(2912) , HMAX)                                      AMRK0140
      EQUIVALENCE (C(2911) , HMIN)                                      AMRK0150
      EQUIVALENCE (J1,N1)                                               AMRK0160
```

```
      IF (CNCE) 2,1,2                                                   ANRK0220
    1 CNCE = 1                                                          ANRK0230
      N = NI - 1                                                        ANRK0240
      CPT = 0.0                                                         ANRK0250
      P1  = 2.2916666666667                                             ANRK0260
      P2  = 2.4583333333333                                             ANRK0270
      P3  = 1.5416666666667                                             ANRK0300
      P4  = 0.375                                                       ANRK0310
      C2  = 0.7916666666667                                             ANRK0320
      C3  = 0.2083333333333                                             ANRK0330
      C4  = 0.0416666666667                                             ANRK0340
      KOUNT = 0                                                         ANRK0350
    2 N1 = N                                                            ANRK0360
      J2=J1+N1                                                          ANRK0370
      J3=J2+N1                                                          ANRK0400
      J4=J3+N1                                                          ANRK0410
      J5=J4+N1                                                          ANRK0420
      J6=J5+N1                                                          ANRK0430
      J7=J6+N1                                                          ANRK0440
      J8=J7+N1                                                          ANRK0450
      J9=J8+N1                                                          ANRK0460
      J10=J9+N1                                                         ANRK0470
      J11=J10+N1                                                        ANRK0500
      J12=J11+N1                                                        ANRK0510
      J13=J12+N1                                                        ANRK0520
      J14=J13+N1                                                        ANRK0530
      J15=J14+N1                                                        ANRK0540
C     IF (CPT.NE 0.) GO TO 60                                           ANRK0550
      IF (OPT) 60,49,60                                                 ANRK0560
C     IF (DELT . EQ. (0.5*D(1))) GO TO 200                              ANRK0570
   49 IF (DELT - (0.5*D(1))) 50,200,50                                  ANRK0600
 50   KOUNT=0                                                           ANRK0610
C                                                                       ANRK0620
C     START RUNGE-KUTTA INTEGRATION.                                    ANRK0630
C     COMPUTE K0                                                        ANRK0640
C                                                                       ANRK0650
   60 CONTINUE                                                          ANRK0660
      DO 25 I=1,N1                                                      ANRK0670
      K5=J15+I                                                          ANRK0700
C     IF(SNGL(T(K5)) .NE. V(I+1))T(K5) = V(I+1)                         ANRK0710
      IF(SNGL(T(K5)) - V(I+1)) 24,25,24                                 ANRK0720
   24 T(K5) = V(I+1)                                                    ANRK0730
 25   CONTINUE                                                          ANRK0740
C     IF(SNGL(TME) .NE. V(1)) TME = V(1)                                ANRK0750
   26 TMF=V(1)
   27 KOUNT = KCUNT + 1                                                 ANRK1000
   70 DO 80 I=1,N1                                                      ANRK1010
      K0=J7+I                                                           ANRK1020
```

```
   80 T(K0)=D(1)*D(I+1)                                                 AMRK1030
C                                                                       AMRK1040
C     COMPUTE K1                                                        AMRK1050
C                                                                       AMRK1060
      DELT=0.5*D(1)                                                     AMRK1070
      TME=DELT+TME                                                      AMRK1100
      V(1)=TME                                                          AMRK1110
      DO 90 I=1,N1                                                      AMRK1120
      K0=J7+I                                                           AMRK1130
      K1=J11+I                                                          AMRK1140
      K2=J12+I                                                          AMRK1150
      K3=J13+I                                                          AMRK1160
      K5=J15+I                                                          AMRK1170
      T(I)=D(I+1)                                                       AMRK1200
      T(K1)=T(K2)                                                       AMRK1210
      T(K2)=T(K3)                                                       AMRK1220
      T(K3)=T(K5)                                                       AMRK1230
      T(K5) =T(K5) +0.5*T(K0)                                           AMRK1240
   90 V(I+1)=T(K5)                                                      AMRK1250
      CALL AUXSUB                                                       AMRK1260
      DO 100 I=1,N1                                                     AMRK1270
      K1=J8+I                                                           AMRK1300
  100 T(K1)=D(1)*D(I+1)                                                 AMRK1310
C                                                                       AMRK1320
C     COMPUTE K2                                                        AMRK1330
C                                                                       AMRK1340
      DO 110 I=1,N1                                                     AMRK1350
      K5=J15+I                                                          AMRK1360
      K1=J8+I                                                           AMRK1370
      K0=J7+I                                                           AMRK1400
      T(K5) =T(K5) +0.5*(T(K1)-T(K0))                                   AMRK1410
  110 V(I+1)=T(K5)                                                      AMRK1420
      CALL AUXSUB                                                       AMRK1430
      DO 120 I=1,N1                                                     AMRK1440
      K2=J9+I                                                           AMRK1450
  120 T(K2)=D(1)*D(I+1)                                                 AMRK1460
C                                                                       AMRK1470
C     COMPUTE K3                                                        AMRK1500
C                                                                       AMRK1510
      TME=DELT+TME                                                      AMRK1520
      V(1)=TME                                                          AMRK1530
      DO 130 I=1,N1                                                     AMRK1540
      K5=J15+I                                                          AMRK1550
      K2=J9+I                                                           AMRK1560
      K1=J8+I                                                           AMRK1570
      T(K5) =T(K5) +T(K2)-0.5*T(K1)                                     AMRK1600
  130 V(I+1)=T(K5)                                                      AMRK1610
      CALL AUXSUB                                                       AMRK1620
```

```
      DO 140 I=1,N1                                                     AMRK1630
      K3=J10+I                                                          AMRK1640
  140 T(K3)=D(1)*D(I+1)                                                 AMRK1650
C                                                                       AMRK1660
C     COMPLTE VALUE OF FUNCTION.                                        AMRK1670
C                                                                       AMRK1700
      DO 15C I=1,N1                                                     AMRK1710
      K0=J7 +I                                                          AMRK1720
      K1=J8 +I                                                          AMRK1730
      K2=J9 +I                                                          AMRK1740
      K3=J10+I                                                          AMRK1750
      K5=J15+I                                                          AMRK1760
      T(K5)=T(K5)+0.1666666666666667*                                   AMRK1770
     1(T(KC)+T(K1)+T(K1)-4.*T(K2)+T(K3))                                AMRK2000
      V(I+1)=T(K5)                                                      AMRK2010
  150 CCNTINLE                                                          AMRK2020
  17C CONTINLE                                                          AMRK2030
      CALL ALXSUB                                                       AMRK2040
      DO 180 I=1,N1                                                     AMRK2050
      K5=J1+I                                                           AMRK2060
      K0=J2+I                                                           AMRK2070
      K1=J3+I                                                           AMRK2100
      K2=J4+I                                                           AMRK2110
      K3=J5+I                                                           AMRK2120
      K4=J6+I                                                           AMRK2130
      T(K4)=T(K3)                                                       AMRK2140
      T(K3)=T(K2)                                                       AMRK2150
      T(K2)=T(K1)                                                       AMRK2160
      T(K1)=T(K0)                                                       AMRK2170
      T(KC)=T(K5)                                                       AMRK2200
      T(K5)=T(I)                                                        AMRK2210
       T(I)=D(I+1)                                                      AMRK2220
 180  CONTINLE                                                          AMRK2230
 190   CONTINLE                                                         AMRK2240
      RETURN                                                            AMRK2250
C                                                                       AMRK2260
C     DO ADAMS-MCULTON INTEGRATION                                      AMRK2270
C                                                                       AMRK2300
 200  CONTINLE                                                          AMRK2310
C     IF (KCLNT .LT. 3) GO TO 60                                        AMRK2320
      IF (KCLNT - 3) 60,201,201                                         AMRK2330
  201 KOUNT = KCLNT + 1                                                 AMRK2340
      DELT=D(1)*.5                                                      AMRK2350
      DO 210 I=1,N1                                                     AMRK2360
      K0=J7+I                                                           AMRK2370
      K1=J2+I                                                           AMRK2400
      K2=J3+I                                                           AMRK2410
      K4=J1+I                                                           AMRK2420
```

```
      K5=J15+I                                                          ANRK2430
C                                                                       ANRK2440
C     COMPUTE Y-PREDICTED.                                              ANRK2450
C                                                                       ANRK2460
      T(KO)=T(K5)                                                       ANRK2470
      T(K5) =T(KO)+D(1)*(P1*T(I)-P2*T(K4)+P3*T(K1)-P4*T(K2))            ANRK2500
  210 V(I+1)=T(K5)                                                      ANRK2510
      TME=TME+D(1)                                                      ANRK2520
      V(1)=TME                                                          ANRK2530
      CALL AUXSUB                                                       ANRK2540
      K5=0                                                              ANRK2550
      DO 220 I=1,N1                                                     ANRK2560
      KO=J8+I                                                           ANRK2570
      K2=J2+I                                                           ANRK2600
      K1=J7+I                                                           ANRK2610
      K4=J1+I                                                           ANRK2620
      K3=J15+I
C                                                                       ANRK2630
C     COMPUTE Y-CORRECTED                                               ANRK2640
C                                                                       ANRK2650
      T(KO)=T(K1) +D(1)*(P4*D(I+1)+C2*T(I)-C3*T(K4)+T(K2)*C4)           ANRK2660
      ERF=14.*DMAX1(DABS(T(K1)),.01D0)
      ERU=ERF*EL(I)
      ERL=ERF*EL(I)
      TEMP = DABS(T(KO)-T(K3))
C     IF TEMP.LT.ERU) GO TO 215
      IF (TEMP-ERU) 215,214,214
C     IF(ABS(SNGL(DELT)) .GE. HMIN) GO TO 260                           ANRK2720
  214 IF(ABS(SNGL(DELT)) - HMIN) 215,260,260                            ANRK2730
  215 CONTINUE                                                          ANRK2740
C     IF (TEMP.LT.ERL)  K5=K5+1
      IF (TEMP-ERL) 216,220,220
  216 K5 = K5 + 1                                                       ANRK2770
  220 CONTINUE                                                          ANRK3000
C     IF(K5 .LT. N1) GO TO 300                                          ANRK3010
      IF(K5 - N1) 300,221,221                                           ANRK3020
C     IF(ABS(D(1) + D(1)) .GT. HMAX) GO TO 300                          ANRK3030
  221 IF(ABS(D(1) + D(1)) - HMAX) 222,222,300                           ANRK3040
C                                                                       ANRK3050
C     SET-UP FOR DOUBLING STEP SIZE                                     ANRK3060
C                                                                       ANRK3070
C     IF(KOUNT .LE. 6) GO TO 300                                        ANRK3100
  222 IF(KOUNT - 6) 300,300,223                                         ANRK3110
  223 CONTINUE                                                          ANRK3120
      DO 240 I=1,N1                                                     ANRK3130
      K1=J1+I                                                           ANRK3140
       K2=J2+I                                                          ANRK3150
      K3=J3+I                                                           ANRK3160
```

```
      K5=J5+I                                                           ANRK3170
      T(I)=T(K1)                                                        ANRK3200
      T(K1)=T(K3)                                                       ANRK3210
  240 T(K2)=T(K5)                                                       ANRK3220
      D(1)=D(1)+D(1)                                                    ANRK3230
      KOUNT=4                                                           ANRK3240
      DELT=.5*D(1)                                                      ANRK3250
      GO TO 300                                                         ANRK3260
C                                                                       ANRK3270
C     SET-UP FOR HALVING STEP SIZE.                                     ANRK3300
C                                                                       ANRK3310
  260 CONTINUE                                                          ANRK3320
C     IF(KOUNT .LE. 4) GO TO 350                                        ANRK3330
      IF(KOUNT - 4) 350,350,261                                         ANRK3340
  261 TME=TME-D(1)                                                      ANRK3350
      V(1)=TME                                                          ANRK3360
      D(1)=DELT                                                         ANRK3370
      DELT=.5*D(1)                                                      ANRK3400
      DO 265 I=1,N1                                                     ANRK3410
      K0=J7+I                                                           ANRK3420
      K1=J1+I                                                           ANRK3430
      K2=J2+I                                                           ANRK3440
      K3=J3+I                                                           ANRK3450
      K5=J15+I                                                          ANRK3460
      T(K5)=T(K0)                                                       ANRK3470
      V(I+1)=T(K0)                                                      ANRK3500
      T(K3)=T(K2)+0.5*(T(K1)-T(K2))                                     ANRK3510
      T(K2)=T(K1)                                                       ANRK3520
  265 T(K1)=T(K1)+0.5*(T(I)-T(K1))                                      ANRK3530
      KOUNT=4                                                           ANRK3540
      GO TO 200                                                         ANRK3550
C                                                                       ANRK3560
C          INTEGRATION IS FINISHED. SET UP DERIVATIVES AND EXIT.        ANRK3570
C                                                                       ANRK3600
  300 DO 310 I=1,N1                                                     ANRK3610
      K5=J15+I                                                          ANRK3620
      K0=J8+I                                                           ANRK3630
      T(K5)=T(K0)                                                       ANRK3640
  310 V(I+1)=T(K0)                                                      ANRK3650
      GO TO 170                                                         ANRK3660
  350 CONTINUE                                                          ANRK3670
C                                                                       ANRK3700
C          RETURN TO 3RD RK INTEGRATION AND RESTART                     ANRK3710
C                                                                       ANRK3720
      DO 360 I=1,N1                                                     ANRK3730
      K5=J15+I                                                          ANRK3740
      K1=J11+I                                                          ANRK3750
      T(K5)=T(K1)                                                       ANRK3760
```

```
  360 V(I+1)=T(K1)                                                            ANRK3770
      TME=TME-C(1)*4.                                                         ANRK4000
      V(1)=TME                                                                ANRK4010
       D(1)=DELT                                                              ANRK4020
      CALL ALXSUB                                                             ANRK4030
      GO TO 50                                                                ANRK4040
      END                                                                     ANRK4050
C
C
C
      SUBROUTINE PROCES
      RETURN
      END
C
C
C
      SUBROUTINE RESET
C
      COMMON C(3415)
      EQUIVALENCE (C(2300),NOLIST),(C(2301),LISTNO(1)),(C(2351),
     1 VALUE(1))
      EQUIVALENCE (C(2675),KRUN)
      DIMENSION LISTNO(50), VALUE(50)
      IF(NOLIST.EQ.0) RETURN
      DO 1 I=1,NOLIST
      J=LISTNO(I)
    1 C(J)=VALUE(I)
      KRUN=KRUN+1
      RETURN
      END
C
C
C
      SUBROUTINE INPT1                                                        INPT0010
C
      COMMON C(3415)
      COMMON/CRUS/ ENG(30),IENG(15)
      NAMELIST /MCNT/ ENG,IENG                                                  F   96
      EQUIVALENCE (C(2675), KRUN)
      FLG1=0.0
      IF (KRUN.GT.0) GO TO 100
      READ (5,MCNT)                                                             F  106
      WRITE (6,MCNT)                                                            F  108
  100 RETURN
      END
C
C
      SUBROUTINE INPT2                                                        INPT0010
```

```
      RETURN                                                            INPT0020
      END                                                               INPT0030
C
C
      SUBROUTINE INPT3                                                  INPT0010
      RETURN                                                            INPT0020
      END                                                               INPT0030
C
C
      SUBROUTINE OUPT1                                                  OUPT0010
      RETURN                                                            OUPT0020
      END                                                               OUPT0030
C
C
C
      SUBROUTINE OUPT2                                                  OUTP0020
C
C     OUTPUT INITIALIZATION SUBROUTINE OUPT2                            OUTP0010
C
      COMMON C(3415)                                                    OUTP0030
      INTEGER PGCNT,DTCNT                                               OUTP0130
      EQUIVALENCE    (C(2660),DTCNT)                                    OUTP0040
      EQUIVALENCE    (C(2661),NCOUT)                                    OUTP0050
      EQUIVALENCE    (C(2662),PGCNT)                                    OUTP0060
      EQUIVALENCE (C(2667),ITCNT),(C(2668),PCNT),(C(2669),CPP )         OUTP0070
      EQUIVALENCE (C(2670), TAPE), (C(2671), TAPEND)                    OUTP0100
      EQUIVALENCE (C(2909),DCC)                                         OUTP0110
      EQUIVALENCE(C(2910),KCONV)                                        OUTP0120
      KCONV=0                                                           OUTP0140
      ITCNT = DCC + 1.0                                                 OUTP0150
      PCNT = 0.0                                                        OUTP0160
      PGCNT = 1                                                         OUTP0170
      DTCNT = (NOCUT + 4)/5                                             OUTP0200
C     IF (ITCNT .GE. 7) GO TO 2                                         OUTP0210
      IF (ITCNT - 7) 1,2,2                                              OUTP0220
    1 WRITE (6,6) (I,C(I),C(I+1),C(I+2),C(I+3),C(I+4),C(I+5),C(I+6),    OUTP0230
     1  C(I+7),I=1,3415,8)                                              OUTP0240
    6 FORMAT(1H1/(I5,2X,8E14.7))                                        OUTP0250
    2 TAPEND = 0.                                                       OUTP0260
      K = TAPE                                                          OUTP0270
C     IF (K. NE. 0) REWIND K                                            OUTP0300
      IF (K) 3,4,3                                                      OUTP0310
    3 REWIND K                                                          OUTP0320
    4 RETURN                                                            OUTP0330
      END                                                               OUTP0340
C
C
C
```

```
      SUBROUTINE CLPT3                                                  CLPT0020
C
C     CUTPLT SUBROUTINE CUPT3                                           CLPT0010
C
      DIMENSION B(50),OUTNO(50),ONAME1(50),ONAME2(50)                   CLPT0170
      DIMENSION ONAME3(50)
      COMMON C(3415)                                                    CLPT0030
      INTEGER DTCNT,PGCNT,CUTNO                                         CLPT0200
      EQUIVALENCE (C(2500),CUTNO(1))
      EQUIVALENCE (C(2550),ONAME1(1))
      EQUIVALENCE (C(2600),ONAME2(1))
      EQUIVALENCE (C(2150) , ONAME3(1))
      EQUIVALENCE   (C(2660),DTCNT)                                     CLPT0070
      EQUIVALENCE   (C(2661),NOOUT)                                     CLPT0100
      EQUIVALENCE   (C(2662),PGCNT)                                     CLPT0110
      EQUIVALENCE (C(2667),ITCNT),(C(2668),PCNT),(C(2669),CPP)          CLPT0120
      EQUIVALENCE   (C(932), T)                                         CLPT0130
      EQUIVALENCE (C(2913), DER)                                        CLPT0140
      EQUIVALENCE (C(2670), TAPE), (C(2671), TAPEND)                    CLPT0150
      EQUIVALENCE (C(0290),XTP),(C(0298),YTP),(C(0306),ZTP)             CLPT0160
      EQUIVALENCE (C(3400),PUNCH)
      EQUIVALENCE (C(0521),THET)
      EQUIVALENCE (C(0522),PSI)
      EQUIVALENCE (C(0523),PHI)
      EQUIVALENCE (C(0554),AXECI)
      EQUIVALENCE (C(0555),AYECI)
      EQUIVALENCE (C(0556),AZECI)
      EQUIVALENCE (C(0577),VXECI)
      EQUIVALENCE (C(0552),VYECI)
      EQUIVALENCE (C(0553),VZECI)
      EQUIVALENCE (C(0547),XECI)
      EQUIVALENCE (C(0548),YECI)
      EQUIVALENCE (C(0549),ZECI)
C     IF (ITCNT .GT. 6) GO TO 7                                         CLPT0210
      IF (ITCNT - 6) 10,10,7                                            CLPT0220
   10 ITCNT = ITCNT + 1                                                 CLPT0230
      WRITE (6,6) (I,C(I),C(I+1),C(I+2),C(I+3),C(I+4),C(I+5),C(I+6),    CLPT0240
     1 C(I+7),I=1,3415,8)                                               CLPT0250
    6 FORMAT(1H1/(I5,2X,8E14.7))                                        CLPT0260
      PGCNT = 1                                                         CLPT0270
    7 CONTINUE
C   8 IF (T .LT. PCNT) RETURN                                           CLPT0340
    8 IF (T - PCNT) 12,9,9                                              CLPT0350
   12 RETURN                                                            CLPT0360
    9 PCNT=PCNT+CPP
C     IF (PGCNT .NE. 1) GO TO 3                                         CLPT0400
      IF (PGCNT - 1) 3,1,3                                              CLPT0410
    1 WRITE(6,2) (ONAME1(I),ONAME2(I),ONAME3(I), I = 1, NOOUT)
```

```
    2 FORMAT (1H1,5X,4HTIME,5X,5(8X,3A4)//(23X,3A4,8X,3A4,8X,3A4,8X,
     1 3A4,8X,3A4)/)
      PGCNT = 2*DTCNT + 4                                              CLPT0450
C   3 IF (PGCNT .GE. 58) GO TO 1                                       CLPT0460
    3 IF (PGCNT - 58) 13,1,1                                           CLPT0470
   13 DO 4 I =1, NCOUT                                                 CLPT0500
      J = OUTNC(I)                                                     CLPT0510
    4 B(I) = C(J)                                                      CLPT0520
      K = TAPE                                                         CLPT0530
C     IF (K .NE. 0) WRITE (K) T,XTP,YTP,ZTP,TAPEND, (B(I),I=1,NOOUT)   CLPT0540
      IF (K) 14,15,14                                                  CLPT0550
   14 WRITE (K) T,XTP,YTP,ZTP,TAPEND, (B(I),I=1,NCOUT)                 CLPT0560
   15 WRITE (6,5) T,(B(I),I=1,NOOUT)                                   CLPT0570
    5 FORMAT (////2X,E15.8,5E20.8/(17X,5E20.8))                        CLPT0600
 22   FORMAT(F5.1,3E10.4,3E15.9)
      IF(PUNCH)20,20,21
  21  WRITE(17,22) T,AXECI,AYECI,AZECI,XECI,YECI,ZECI
      WRITE(17,22) T,VXECI,VYECI,VZECI,THET,PSI,PHI
  20  CONTINUE
      PGCNT = PGCNT + DTCNT + 4                                        CLPT0610
      RETURN                                                           CLPT0620
      END                                                              CLPT0630
C
C
      SUBROUTINE STGE1                                                 STGE0010
      RETURN                                                           STGE0020
      END                                                              STGE0030
C
C
C
      SUBROUTINE STGE2                                                 STGE0010
C
      COMMON C(3415)                                                   STGE0020
      EQUIVALENCE (C(2904),KSTEP)                                      STGE0030
      EQUIVALENCE (C(2910), KCONV)                                     STGE0040
      EQUIVALENCE  (C(2672) , LCONV       )                            STGE0050
      KCONV = 0                                                        STGE0060
      LCONV = 0                                                        STGE0070
      KSTEP = 1                                                        STGE0100
      RETURN                                                           STGE0110
      END                                                              STGE0120
C
C
C
      SUBROUTINE STGE3                                                 STGE0140
C
C     THIS OPERATIONAL SUBROUTINE STAGES WHEN IMPACT IS MADE WITH THE  STGE0010
C     EARTH, WHEN FINAL TIME TF IS REACHED, OR WHEN ANOTHER PART OF THE STGE0020
```

```
C       PRCGRAM SETS LCONV = 2.  STAGING WILL OCCUR WHEN THE VEHICLE IS    STGE0030
C       WITHIN + CR - ONE FCCT OF THE EARTH SURFACE, WHEN T IS WITHIN + CRSTGE0040
C       - C.CCC1 SECCND OF TF, OR ACCORDING TO SOME CRITERION IN ANOTHER   STGE0050
C       MODULE CR SUBROUTINE.  FCR EXAMPLE, IF STAGING IS DESIREC AT       STGE0060
C       COINCIDENCE BETWEEN A ANC B, THE FOLLOWING FCRTRAN STATEMENTS      STGE0070
C       SHOULC BE USED IN ONE OF THE SUBROUTINES OF MODULES --             STGE0100
C                                                                          STGE0110
C       IF(ABS(A-B) .LE. 0.5) LCCNV = 2                                    STGE0120
C       IF( (B-A) .LT. 0.) LCONV = 1                                       STGE0130
        DIMENSICN STATNO(100),RMS(10)                                      STGE0270
        COMMCN C(3415)                                                     STGE0150
        INTEGER STATNO                                                     STGE0300
        EQUIVALENCE  (C(932),T),(C(2913),DER)                              STGE0160
        EQUIVALENCE (C(2668),PCNT)                                         STGE0170
        EQUIVALENCE (C(0550),TF), (C(0507),H)                              STGE0200
        EQUIVALENCE (C(2904),KSTEP), (C(2905),STEP)                        STGE0210
        EQUIVALENCE (C(2670), TAPE), (C(2671), TAPEND)                     STGE0220
        EQUIVALENCE (C(2441),NOSTAT),(C(2200),STATNC(1)),(C(2430),RMS(1))
        EQUIVALENCE (C(2442),LCSTAT)                                       STGE0240
        EQUIVALENCE (C(2910), KCCNV)                                       STGE0250
        EQUIVALENCE  (C(2672) , LCONV      )                               STGE0260
C       IF (ABS(H) .LE. 1.0) GO TO 2                                       STGE0310
        IF (ABS(H)-1.0) 2,2,5                                              STGE0320
C       IF (H .LT. C.) GO TC 1                                             STGE0330
      5 IF (H) 1,6,6                                                       STGE0340
C       IF (ABS(T-TF) .LE. 0.0001) GO TO 2                                 STGE0350
      6 IF (ABS(T-TF) - 0.0CC1) 2,2,7                                      STGE0360
C       IF ( (TF-T) .LT. 0.) GC TO 1                                       STGE0370
      7 IF (TF-T) 1,8,8                                                    STGE0400
C       IF (LCCNV .EQ. 2) GC TO 2                                          STGE0410
      8 IF (LCCNV - 2) 9,2,9                                               STGE0420
C       IF (LCCNV .EQ. 1) GC TO 1                                          STGE0430
      9 IF (LCCNV - 1) 10,1,10                                             STGE0440
C       IF (CER .LT. 0.) DER = -CER*0.5                                    STGE0450
     1C IF (CER) 11,12,12                                                  STGE0460
     11 CER = -CER*0.5                                                     STGE0470
     12 RETURN                                                             STGE0500
C     1 IF (CER .GT. 0.) DER = -CER*0.5                                    STGE0510
      1 IF (DER) 14,14,13                                                  STGE0520
     13 DER = -DER*0.5                                                     STGE0530
     14 KCCNV = KCCNV + 1                                                  STGE0540
C       IF (KCCNV .GE. 10) GC TC 2                                         STGE0550
        IF (KCCNV - 10) 15,2,2                                             STGE0560
     15 RETURN                                                             STGE0570
      2 PCNT = 1.C                                                         STGE0600
        TAPENC = 1.                                                        STGE0610
        CALL CLFT3                                                         STGE0620
        K = TAPE                                                           STGE0630
```

```
C     IF (K .NE. 0) END FILE K                                          STGE0640
C     IF (K .NE. 0) REWIND K                                            STGE0650
      IF (K) 16,17,16                                                   STGE0660
   16 END FILE K                                                        STGE0670
      REWIND K                                                          STGE0700
   17 KSTEP = 2                                                         STGE0710
C     IF (LOSTAT .EQ. NOSTAT) GO TO 4                                   STGE0720
      IF (LOSTAT - NOSTAT) 18,4,18                                      STGE0730
   18 L = LOSTAT + 1                                                    STGE0740
      DO 3 I = L, NOSTAT                                                STGE0750
      M = STATNO(I)                                                     STGE0760
    3 RMS(I) = C(M)                                                     STGE0770
    4 RETURN                                                            STGE1000
      END                                                               STGE1010
C
C
      SUBROUTINE CNTR1                                                  CNTR0010
      RETURN                                                            CNTR0020
      END                                                               CNTR0030
C
C
      SUBROUTINE CNTR2                                                  CNTR0010
      RETURN                                                            CNTR0020
      END                                                               CNTR0030
C
C
      SUBROUTINE CNTR3                                                  CNTR0010
      RETURN                                                            CNTR0020
      END                                                               CNTR0030
C
C
      SUBROUTINE RNDM1                                                  RNDM0010
      RETURN                                                            RNDM0020
      END                                                               RNDM0030
C
C
C
      SUBROUTINE RNDM2
C
      COMMON C(3415)
      EQUIVALENCE (C(2443), RNFLG)
      EQUIVALENCE (C(2446), ZN)
      EQUIVALENCE (C(2448), NORNDM)
      EQUIVALENCE (C(2449), DELT)
      EQUIVALENCE (C(2450), RNDMNO)
      EQUIVALENCE (C(2913), DER)
      DIMENSION RNDMNO(50)
      INTEGER RNDMNO
```

```
      IF (NCRNDM) 2,2,3
    3 RNFLG=C.
      DELT=DER
      DO 1 I=1,NCRNDM
      J=RNDMNC(I)
      C(J+5)=2.718281828**(-DER*C(J+4))
      C(J+6)=C(J+3)*SQRT(1.0-C(J+5)*C(J+5))
      ZN=C(J+1)
      Y=C(J)
      N=INT(Y)
      CALL RFG(N,X)
      C(J+7)=C(J+3)*X
    1 C(J+1)=ZN
    2 RETURN
      END
C
C
C
      SUBROUTINE RNDM3
C
      COMMON C(3415)
      EQUIVALENCE (C(2443), RNFLG)
      EQUIVALENCE (C(2444), RN)
      EQUIVALENCE (C(2446), ZN)
      EQUIVALENCE (C(2448), NORNDM)
      EQUIVALENCE (C(2449), DELT)
      EQUIVALENCE (C(2450), RNDMNO)
      EQUIVALENCE (C(2913), DER)
      DIMENSION RNDMNO(50)
      INTEGER RNDMNO
      IF (NCRNDM) 20,20,10
   10 IF (RNFLG.GE.1.0) GO TO 8
      IF (DER.GE.0.) GO TO 6
    8 DO 9 I=1,NCRNDM
      J=RNDMNO(I)
      X=(C(J+7)-C(J+5)*C(J+8))/C(J+6)
      IF (RNFLG.GE.1.0)  GO TO 5
      RNFLG=1.C
      DELT=-DER
      GO TO 7
    5 DELT=DELT+DER
    7 C(J+5)=2.718281828**(-DELT*C(J+4))
      C(J+6)=C(J+3)*SQRT(1.-C(J+5)*C(J+5))
    9 C(J+7)=C(J+6)*X+C(J+5)*C(J+8)
      RETURN
    6 IF (DELT.EQ.DER) GO TO 4
    2 DO 3 I=1,NCRNDM
      J=RNDMNO(I)
```

```
      C(J+5)=2.718281828**(-DER*C(J+4))
    3 C(J+6)=C(J+3)*SQRT(1.0-C(J+5)*C(J+5))
      DELT=DER
    4 DO 1 I=1,NORNDM
      J=RNDMNC(I)
      Y=C(J)
      ZN=C(J+1)
      N=INT(Y)
      CALL RFG(N,X)
      C(J+8)=C(J+7)
      C(J+7)=C(J+6)*X+C(J+5)*C(J+7)
    1 C(J+1)=ZN
   20 RETURN
        END
C
C
      SUBROUTINE AUXA1                                                  AUXA0010
      RETURN                                                            AUXA0020
      END                                                               AUXA0030
C
C
      SUBROUTINE AUXA2
      RETURN
      END
C
C
      SUBROUTINE AUXA3
      RETURN
      END
C
C
      SUBROUTINE AUXB1                                                  AUXB0010
      RETURN                                                            AUXB0020
      END                                                               AUXB0030
C
C
      SUBROUTINE AUXB2                                                  AUXB0010
      RETURN                                                            AUXB0020
      END                                                               AUXB0030
C
C
      SUBROUTINE AUXB3                                                  AUXB0010
      RETURN                                                            AUXB0020
      END                                                               AUXB0030
C
C
      SUBROUTINE AUXC1                                                  AUXC0010
      RETURN                                                            AUXC0020
```

```
      END                                                               ALXC0030
C
C
      SUBROUTINE ALXC2                                                  ALXC0010
      RETURN                                                            ALXC0020
      END                                                               ALXC0030
C
C
      SUBROUTINE AUXC3                                                  ALXC0010
      RETURN                                                            ALXC0020
      END                                                               ALXC0030
C
C
C
      SUBROUTINE RFG(N,X)
C
      COMMON C(3415)
      EQUIVALENCE (C(2446), ZN)
      Y=FLOAT(N)
      X=0.0
C     GENERATE UNIFORM RANDOM NO.(0 TO 1)
C    SUM FOR RAND NO(SIGMA=1,MEAN=0)
C     UNIFORM DIST FOR N=1
C     NORMAL DIST FOR LARGE N (12 OR GREATER)
      DO 1 I=1,N
      X=X+ZN-0.5
      RNO=997.*ZN
    1 ZN=RNO-AINT(RNO)
      X=SQRT(12./Y)*X
      RETURN
      END
C
C
C
      SUBROUTINE A1I
C
C     AERODYNAMIC FORCES AND MOMENTS INITIALIZATION MODULE A1I
C     BODY AXES
C
      COMMON C(3415)
      EQUIVALENCE  (C(0208) , TSA   )
      EQUIVALENCE  (C(0257) , CTS   )
      EQUIVALENCE  (C(0258) , STS   )
      CTS = COS(TSA)
      STS = SIN(TSA)
      RETURN
      END
C
```

```
C
C
      SUBROUTINE A1
C
C     AERODYNAMIC FORCES AND MOMENTS MODULE A1 - BODY AXES
C
      COMMON C(3415)
      EQUIVALENCE (C(0110), S)
      EQUIVALENCE (C(0111), CA)
      EQUIVALENCE (C(0113), CY)
      EQUIVALENCE (C(0115), CZ)
      EQUIVALENCE (C(0116), CBAR)
      EQUIVALENCE (C(0118), CMQ)
      EQUIVALENCE (C(0119), CNR)
      EQUIVALENCE (C(0120), CLP)
      EQUIVALENCE (C(0121), CM)
      EQUIVALENCE (C(0122), CN)
      EQUIVALENCE (C(0123), CL)
      EQUIVALENCE (C(0128), FXBA)
      EQUIVALENCE (C(0129), FYBA)
      EQUIVALENCE (C(0130), FZBA)
      EQUIVALENCE (C(0131), CLBA)
      EQUIVALENCE (C(0132), CMBA)
      EQUIVALENCE (C(0133), CNBA)
      EQUIVALENCE (C(0212), PBA)
      EQUIVALENCE (C(0216), QBA)
      EQUIVALENCE (C(0220), RBA)
      EQUIVALENCE (C(0257), CTS)
      EQUIVALENCE (C(0258), STS)
      EQUIVALENCE (C(0508), QD)
      EQUIVALENCE (C(0529), VAT)
      QDS=QD*S
      QDSC=QDS*CBAR
      DIM=CBAR/(2.0*VAT)
C    AERODYNAMIC MOMENTS (BODY AXES)
      CLBA=QDSC*(CL+CLP*DIM*PBA)
      CMBA=QDSC*(CM+CMQ*DIM*QBA)
      CNBA=QDSC*(CN+CNR*DIM*RBA)
C    AERODYNAMIC FORCES (BODY AXES)
      FXBA=QDS*CA
      FYBA=QDS*CY
      FZBA=QDS*CZ
      RETURN
      END
C
C
      SUBROUTINE A2I
      RETURN
```

```
      END
C
C
C
      SUBROUTINE A2
C
C    CAB - ZERO-LIFT BODY DRAG
C    CAC - DRAG DUE TO DEFLECTED CONTROL SURFACES
C    CA - CAB+CAC
C    CZB - NORMAL FORCE DUE TO ANGLE OF ATTACK
C    CZC - NORMAL FORCE DUE TO FIN DEFLECTION
C    CZ - NORMAL FORCE
C    CYB - SIDE FORCE DUE TO SIDESLIP
C    CYC - SIDE FORCE DUE TO FIN DEFLECTION
C    CY - SIDE FORCE
C    CMQ - PITCH DAMPING MOMENT
C    CNR - YAW DAMPING MOMENT
C    CLP - ROLL DAMPING MOMT
C    CMB - PITCH MOMENT DUE TO ANGLE OF ATTACK
C    CMC - CONTROL SURFACE PITCH MOMENT
C    CM - CMB+CMC
C    CNB - YAW MOMENT DUE TO SIDESLIP
C    CNC - CONTROL SURFACE YAW MOMENT
C    CN  - CNB+CNC
C    CLB - INDUCED ROLL MOMENT
C    CLC - CONTROL SURFACE ROLL MOMENT
C    CL  - CLB+CLC
C
      COMMON/APPLE/TM1(7),TM2(15),TM3(14),TM4(5),TETA1(7),TETA2(7),
     1TETA3(6),TXI1(2),TXI2(10),TXI3(5),TDELT(4),TH1(3),TH2(2),
     2TCZBC(7,2,7),TDCZP(14,7),TCYBC(7,10,6),TCMBC(7,5,7),TDCMF(14,7),
     3TCDB(15,2),TCDC(15,2),TCAD2(15),TCNBC(7,10,6),TCMD1(15,4),
     4TCMD2(5,4),TCCMD(15),TCCMCA(15),TPMD(14,3),TCMQ(15),TPQ(14,3),
     5TCLBC(7,10,6),TCLD(15),TPLD(14,3),TCLP(15),TPP(14,3),TDCYSP(3),
     LTDCZSP(3),TDCMSP(3),TDCNSP(3),TH3(3),TFEJ(13),TTEJ(13)
      COMMON C(3415)
      EQUIVALENCE (C(0016), DP)
      EQUIVALENCE (C(0020),DG)
      EQUIVALENCE (C(0024),DR)
      EQUIVALENCE (C(0111),CA)
      EQUIVALENCE (C(0113),CY)
      EQUIVALENCE (C(0114), XI)
      EQUIVALENCE (C(0115),CZ)
      EQUIVALENCE (C(0116),CBAR)
      EQUIVALENCE (C(0117),ETA)
      EQUIVALENCE (C(0118),CMQ)
      EQUIVALENCE (C(0119),CNR)
      EQUIVALENCE (C(0120),CLP)
```

```
EQUIVALENCE (C(0121),CM )
EQUIVALENCE (C(0122), CN)
EQUIVALENCE (C(0123), CL)
EQUIVALENCE (C(0136), CG)
EQUIVALENCE (C(0259), CGR)
EQUIVALENCE (C(0330), ALF)
EQUIVALENCE (C(0331), BET)
EQUIVALENCE (C(0332), DELQ)
EQUIVALENCE (C(0333), DELR)
EQUIVALENCE (C(0334), DELP)
EQUIVALENCE (C(0507), H)
EQUIVALENCE (C(0509), UBA)
EQUIVALENCE (C(0510), VBA)
EQUIVALENCE (C(0511), WBA)
EQUIVALENCE (C(0518), ASA)
EQUIVALENCE (C(0519), BSA)
EQUIVALENCE (C(0520), AM)
EQUIVALENCE (C(0529), VAT)
EQUIVALENCE (C(0932), T)
EQUIVALENCE (C(0933), T1)
EQUIVALENCE (C(0935), T3)
EQUIVALENCE (C(0936), T4)
EQUIVALENCE (C(1696), RDUL)
EQUIVALENCE (C(1700), RDUR)
EQUIVALENCE (C(1704), RDLL)
EQUIVALENCE (C(1708), RDLR)
EQUIVALENCE (C(0109), FLGSEP)
EQUIVALENCE (C(0306), ZTP)
EQUIVALENCE (C(0523), PHI)
RAD=57.2957795
ALF=ASA*RAD
BET=BSA*RAD
DUL=RDUL*RAD
DUR=RDUR*RAD
DLL=RDLL*RAD
DLR=RDLR*RAD
DELQ=DQ*RAD
DELR=DR*RAD
DELP=DP*RAD
ADUL=ABS(DUL)
ADUR=ABS(DUR)
ADLL=ABS(DLL)
ADLR=ABS(DLR)
COSETA=UBA/VAT
IF (COSETA.GE.1.0)  COSETA=1.0
IF (COSETA.GE.1.0)  COSETA=1.0
ETAR =ARCOS(COSETA)
ETA=ETAR*RAD
```

```
      VN=SQRT(VBA**2+WBA**2)
      IF (VN.LT.0.00001) GO TO 10
      XIR=ATAN2(VBA,WBA)
      GO TO 20
   10 XIR=0.0
   20 XI=XIR*RAD
      XI1=XI
      IF (XI.LT.0.0) XI1=-XI
      XI2=XI1
      IF (XI1.GE.90.) XI2=180.-XI1
C    TABLE LOOK-UP,ALL PHASES
      DCZP=0.0
      DCMP=0.0
      PMD=1.0
      PND=1.0
      PLD=1.0
      PQ=1.0
      PR=1.0
      PP=1.0
      DCMSEP=0.
      DCNSEP=0.
      DCLSEP=0.
      DCYSEP=0.
      DCZSEP=0.
      DCLSP=0.
      DCNSP=0.
      DCYSP=0.
C     MOMENT COEFFICIENTS
C      PITCHING MOMENT
      CMBCC=THREDL(AM,XI2,ETA,TM1,TXI3,TETA1,TCMBC,7,5,7)
      DCMUL=ODLI(AM,TM2,TDCMD,15)
      DCMUR=DCMLL
      DCMLL=-DCMUL
      DCMLR=-DCMUL
      DCMULA=ODLI(AM,TM2,TDCMDA,15)
      DCMURA=-DCMULA
      DCMLLA=-DCMULA
      DCMLRA=DCMULA
      CMG=ODLI(AM,TM2,TCMG,15)
C      YAWING MOMENT
      CNBC=THREDL(AM,XI2,ETA,TM1,TXI2,TETA3,TCNBC,7,10,6)
      IF (XI1.GT.90.)  CNBC=-CNBC
      IF (XI.LT.0.0)  CNBC=-CNBC
      DCNUL=-DCMUL
      DCNUR=DCMUL
      DCNLL=-DCMLL
      DCNLR=DCMUL
      DCNULB=DCMLLA
```

```
      DCMURB=-DCMULA
      DCMLLB=-DCMULA
      DCMLRB=DCMULA
      CNR=CMC
C     ROLLING MOMENT
      CLBC=THRECL(AM,XI2,ETA,TM1,TXI2,TETA3,TCLBC,7,10,6)
      IF (XI1.GT.90.)  CLBC=-CLBC
      IF (XI.LT.0.)  CLBC=-CLBC
      CLD=CDLI(AM,TM2,TCLD,15)
      CLF=CDLI(AM,TM2,TCLF,15)
C    FORCE COEFFICIENTS
      CZBCC=THRECL(AM,XI2,ETA,TM1,TXI1,TETA1,TCZBC,7,2,7)
      CYBC=THRECL(AM,XI2,ETA,TM1,TXI2,TETA3,TCYBC,7,10,6)
      IF (XI1.GT.9C.)  CYBC=-CYBC
      IF (XI.LT.0.)  CYBC=-CYBC
      CAC2=CDLI(AM,TM2,TCAC2,15)
      IF (T.GE.T3)  GO TO 100
C   TABLE LOOK-UP, SEP AND BOOST PHASE
C    ZERO-LIFT DRAG
      CDO=STDLIA(TM2,TH2,TCDB,AM,H,15,2)
      IF (T.LT.T1)  CDO=CDO+.08
C    CONTROL SURFACE EFFECTIVENESS
      CMULO=STDLIA(TM2,TDELT,TCMD1,AM,ADUL,15,4)
      IF (DUL.LT.0.0)  CMULO=-CMULO
      CMURO=STDLIA(TM2,TDELT,TCMD1,AM,ADUR,15,4)
      IF (DUR.GT.0.0)  CMURO=-CMURO
      CMLLO=STDLIA(TM2,TDELT,TCMD1,AM,ADLL,15,4)
      IF (DLL.LT.0.0)  CMLLO=-CMLLO
      CMLRO=STDLIA(TM2,TDELT,TCMD1,AM,ADLR,15,4)
      IF (DLR.GT.0.0)  CMLRO=-CMLRO
C    PLUME EFFECTS
      IF (AM.GE.1.6)  GO TO 200
      HOK=H/1000.
      PM=2.1212E-06*HOK**3-5.2017E-04*HOK**2+.044193*HOK-9.0909E-04
      DCMP=STDLIA(TM3,TETA2,TDCMP,AM,ETA,14,7)
      IF (DCMP.LT.0.0)  DCMP=0.0
      DCZP=STDLIA(TM3,TETA2,TDCZP,AM,ETA,14,7)
      IF (DCZP.GT.0.0)  DCZP=0.0
      DCMP=DCMP*PM
      DCZP=DCZP*PM
      PMD=STDLIA(TM3,TH1,TPMD,AM,H,14,3)
      IF (PMD.GT.1.0)  PMD=1.0
      PND=PMD
      PLD=STDLIA(TM3,TH1,TPLD,AM,H,14,3)
      IF (PLD.GT.1.0)  PLD=1.0
      PQ=STDLIA(TM3,TH1,TPQ,AM,H,14,3)
      IF (PQ.GT.1.0)  PQ=1.0
      PR=PQ
```

```
      PP=STCLIA(TM3,TH1,TFF,AM,H,14,3)
      IF (FP.GT.1.0)  PP=1.C
C     SEPARATICN EFFECTS
      IF (FLGSEP.LE.0.) GC TC 200
      IF (T.GE.1.0) GO TO 200
      IF (ZTF.GE.15.) GC TC 200
      FS2=(1.-ZTP/15.)*EXP(-ZTF/15.)
      CCMSFF=CCLI(H,TH3,TCCMSP,3)
      DCZSFP=CCLI(H,TH3,TCCZSP,3)
      CCMSF=FS2*CCMSPP
      DCZSF=FS2*CCZSPP
      IF (ZTP.GE.4.0) GO TC 30
      FS1=(1.-ZTP/4.)*EXP(-ZTP/4.)
      DCYSFF=CDLI(H,TH3,TCCYSP,3)
      CCNSPP=ODLI(F,TH3,TCCNSP,3)
      CCYSF=FS1*CCYSPP
      DCNSP=FS1*DCNSPP
      CCLSF=-.13*FS1
   3C CPHI=CCS(FHI)
      SPHI=SIN(PHI)
      CCZSEP=CCZSP*CPHI+DCYSP*SPHI
      DCYSEP=DCYSP*CPHI-DCZSF*SPHI
      CCMSEP=DCMSP*CPHI+DCNSP*SPHI
      CCNSFP=CCNSP*CPHI-CCMSF*SPHI
      DCLSEP=CCLSP
      GO TC 2CC
C     TABLE LCCK UF,CRUISE FHASE
C      ZERC-LIFT CRAG
  100 CDC=STCLIA(TM2,TH2,TCDC,AM,H,15,2)
C     CCNTRCL SURFACE EFFECTIVENESS
      CMULO=STCLIA(TM4,TDELT,TCMD2,AM,ADUL,5,4)
      IF (DUL.LT.0.0)  CMULC=-CMULO
      CMURC=STCLIA(TM4,TDELT,TCMD2,AM,ADUR,5,4)
      IF (CUR.GT.0.0)  CMURO=-CMURO
      CMLLC=STCLIA(TM4,TCELT,TCMD2,AM,ADLL,5,4)
      IF (CLL.LT.0.0)  CMLLC=-CMLLO
      CMLRC=STCLIA(TM4,TCELT,TCMD2,AM,ADLR,5,4)
      IF (CLR.GT.0.0)  CMLRC=-CMLRO
      CLC=CLC+.0017
C     ENC CF TABLE LCCK-UP
  2CC CNULC=CMLLC
      CNURC=-CMLRC
      CNLLC=-CMLLC
      CNLRC=CMLRC
      CZBC=CZBCC+CCZP
      CMBC=CMBCC+CCMP
      CABC=CCC*CCSETA
C     TRANSFORM FROM CROSS-FLCW TO BODY AXIS COMPCNENTS
```

```
      CXI=COS(XIR)
      SXI=SIN(XIR)
      CAB=CABC
      CYB=CYBC*CXI-CZBC*SXI
      CZB=CYBC*SXI+CZBC*CXI
      CLB=CLBC
      CNB=CNBC*CXI-CMBC*SXI
      CMB=CNBC*SXI+CMBC*CXI
C    CONTROL SURFACE MOMENT AND FORCE COEFFICIENTS
C     CONTROL SURFACE CP IS 15.25 FT FROM NOSE
      F=(15.25-CG)/(15.25-CGR)
      CMUL=CMULC+DCMULA*ALP*DUL+DCMUL*ADUL
      CMUR=CMURC+DCMURA*ALP*DUR+DCMUR*ADUR
      CMLL=CMLLC+DCMLLA*ALP*DLL+DCMLL*ADLL
      CMLR=CMLRC+DCMLRA*ALP*DLR+DCMLR*ADLR
      CMC=(CMLL+CMUR+CMLL+CMLR)*F*PMD
      CNUL=CNULC+DCNULB*BET*DUL+DCNUL*ADUL
      CNUR=CNURC+DCNURB*BET*DUR+DCNUR*ADUR
      CNLL=CNLLC+DCNLLB*BET*DLL+DCNLL*ADLL
      CNLR=CNLRC+DCNLRB*BET*DLR+DCNLR*ADLR
      CNC=(CNLL+CNUR+CNLL+CNLR)*F*PND
      CLUL=CLD*DUL
      CLUR=CLD*DUR
      CLLL=CLD*DLL
      CLLR=CLD*DLR
      CLC=(CLLL+CLUR+CLLL+CLLR)*PLD
      CZC=-CMC*CBAR/(15.25-CG)
      CYC=-CNC*CBAR/(15.25-CG)
      CAC=CAD2*(DUL**2+DUR**2+DLL**2+DLR**2+4.*1.3*(ALP*DELQ-BET*DELR))
C    TOTAL AERODYNAMIC FORCE COEFFICIENTS
      CA=CAB+CAC
      CY=CYB+CYC+DCYSEP
      CZ=CZB+CZC+DCZSEP
      CA=-CA
      CZ=-CZ
C    TOTAL AERODYNAMIC MOMENT COEFFICIENTS
      CL=CLB+CLC+DCLSEP
      CLP=CLP*RAD*PP
      CM=CMB+CMC+CZB*(CG-CGR)/CBAR+DCMSEP
      CMQ=CMQ*RAD*PQ
      CN=CNB+CNC+CYB*(CG-CGR)/CBAR+DCNSEP
      CNR=CNR*RAD*PR
      RETURN
      END
C
C
C
C
```

```
      SUBRCUTINE A3I
      COMMCN C(3415)
      COMMCN  /FLAG/  FLG1
      EQUIVALENCE (C(0601), FF1)
      EQLIVALENCE (C(0602), WEIG)
      EQUIVALENCE (C(0603), IA)
      EQUIVALENCE (C(0604), FLG2)
      FF1=C.C
      WEIG=0.C
      IA=0
      FLG1=C.C
      FLG2=0.C
      RETURN
      END
C
C
C
      SUBRCUTINE A3
C
C        THIS IS THE MISSLE PRCPULSION MODULE
C
C   T1=BOCST ENGINE IGNITICN TIME
C   B1=BOOST ENGINE BURNCUT TIME(=T3)
C   BE=CRUISE ENGINE IGNITICN TIME(=T4)
C
      COMMCN  /FLAG/  FLG1
      COMMCN C(3415)
      EQUIVALENCE  (C(0086) , WEIGHT )
      EQUIVALENCE (C(0110), S)
      EQUIVALENCE (C(0932),T)
      EQUIVALENCE (C(0933),T1)
      EQLIVALENCE (C(0935),BT)
      EQUIVALENCE (C(0936),BE)
      EQLIVALENCE (C(0136), CG)
      EQUIVALENCE (C(0150), OLT)
      EQUIVALENCE (C(0151), CMT)
      EQUIVALENCE (C(0152), ONT)
      EQUIVALENCE (C(0153), EPSTH)
      EQLIVALENCE (C(0154), FHITH)
      EQUIVALENCE (C(0201), A)
      EQUIVALENCE (C(0202), B)
      EQLIVALENCE (C(0203), CC)
      EQUIVALENCE (C(0073), TXBA )
      EQUIVALENCE (C(0074), TYEA )
      EQUIVALENCE (C(0075), TZBA )
      EQUIVALENCE (C(0507), H)
      EQUIVALENCE (C(0520), AMACH)
      EQUIVALENCE (C(0117), ETA)
```

```
      EQUIVALENCE (C(0601), FF1)
      EQUIVALENCE (C(0602), WEIG)
      EQUIVALENCE (C(0603), IA)
      EQUIVALENCE (C(0604), FLG2)
      EQUIVALENCE (C(0605) , DIFFM)
      EQUIVALENCE (C(0606), FLGRJ)
      EQUIVALENCE (C(0508), CD)
      EQUIVALENCE (C(2913), DER)
      DATA WFLEL/189./
C
   80 FORMAT(1H,10X,'TOTAL ANGLE OF ATTACK EXCEEDED, ETA=',F8.3)
C
      IF (FLG1.GT.0.0) GO TO 10
      CT = 0.0
      DIFFM=0.
      FF = 0.0
      TXBA = 0.0
      TYBA = 0.0
      TZBA = 0.0
      IF (T.LT.T1) RETURN
      HIN=H*12.*.0254
      TIN=T
      AIN=ETA
      IF (T.GE.BE) GO TO 1
C   BOOST PHASE
      TT=T
      IF (T.GT.ET) GO TO 10
      CALL BOOST (TT,THRUS,FF)
      TXBA=THRUS*COS(EPSTH)
      TNBA=THRUS*SIN(EPSTH)
      TYBA=-TNBA*SIN(PHITH)
      TZBA=TNBA*COS(PHITH)
      IB=0
      WEIGHT=WEIGHT-FF+FF1
      CG=CG-(FF-FF1)/405.94
      A=A-(FF-FF1)/256.25
      B=B-(FF-FF1)/1.881
      CC=B
      CLT=0.
      CMT=TZBA*(15.525-CG)
      CNT=-TYBA*(15.525-CG)
      FF1=FF
      TW=T+DER
      IF(TW.LT.BT) GO TO 2
      IF(FLG2.GT.0.0) GO TO 2
      WEIGHT=WEIGHT-31.
      CG=CG-.15
      FLG2=1.0
```

```
      GO TO 2
   10 CONTINUE
      IF (FLGRJ.GT.0.0) GO TO 21
C     CRUISE PHASE,RAMJET OFF
      IF (IB.GE.1) GO TO 11
      CALL ENGINE(HIN,AMACH,AIN,0.,TIN,1.0,0.,0.,CT,SMARG,-1,1)
      IB=1
   11 IF (AIN.GT.9.3)  AIN=9.3
      CALL ENGINE(HIN,AMACH,AIN,0.,TIN,1.0,0.,0.,CT,SMARG,1,1)
      GO TO 4
C    SIMPLIFIED RAMJET MODEL
C    CRUISE PHASE,RAMJET OFF
   21 CALL RAMJET (HIN,AMACH,AIN,FF,1.0,CT)
      GO TO 4
 1    CONTINUE
      IF (FLGRJ.GT.0.0) GO TO 22
C     CRUISE PHASE,RAMJET ON
      IB=0
      IF (AIN.GT.10.0) GO TO 5
      FF=FF1
      IF (IA.GE.1) GO TO 3
      CALL ENGINE (HIN,AMACH,AIN,FF,TIN,0.0,0.0,0.0,CT,SMARG,-1,1)
      TT=T
      FF1=FF
      IA = 1
 3    XIN=0.0
      IF (WEIG.GT.WFUEL) XIN=1.0
      CALL ENGINE (HIN,AMACH,AIN,FF,TIN,XIN,0.0,0.0,CT,SMARG,1,1)
      GO TO 4
C    SIMPLIFIED RAMJET MODEL
C    CRUISE PHASE,RAMJET ON
   22 IF (AIN.GT.10.0) GO TO 5
      XIN=0.0
      IF (WEIG.GT.WFUEL) XIN=1.0
      CALL RAMJET (HIN,AMACH,AIN,FF,XIN,CT)
      GO TO 4
    5 IF (FLG1.GT.0.0) GO TO 10
      WRITE(6,80) ETA
      FLG1=1.0
      GO TO 10
 4    TXBA=CT*QD*S
      TYBA=0.
      TZBA=0.
      DT=T-TT
      IF (FLGRJ.GT.0.0) GO TO 6
       FF=FF/.45359237
C   DIFFUSER (INLET) MARGIN IS NOT COMPUTED IN SIMPLIFIED RAMJET MODEL
      DIFFM=SMARG/100.
```

```
    6 WEIG=WEIG+(ABS(FF+FF1))*DT/2.0
      IF (WEIG.GT.WFUEL) FLG1=1.0
      WEIGHT = WEIGHT - ABS(FF + FF1)*DT/2.
      TT=T
      FF1 = FF
      CG=CG-.00026455*ABS(FF+FF1)*DT/2.
      A=A-.0031746*ABS(FF+FF1)*DT/2.
      B=B-.063492*ABS(FF+FF1)*DT/2.
      CC = B
  2   RETURN
      END
C
C
C
      SUBROUTINE A4I
C
C     ACTUATOR INITIALIZATION MODULE A4I
C
      COMMON C(3415)
      DIMENSION IPL(100)
      EQUIVALENCE (C(1735),WFIN)
      EQUIVALENCE (C(3315) ,N)
      EQUIVALENCE (C(3316), IPL(1))
      IF (WFIN.GT.0.0) GO TO 100
      GO TO 200
  100 IPL(N)=1693
      IPL(N+1)=1697
      IPL(N+2)=1701
      IPL(N+3)=1705
      IPL(N+4)=1709
      IPL(N+5)=1713
      IPL(N+6)=1717
      IPL(N+7)=1721
      N=N+8
  200 RETURN
      END
C
C
C
      SUBROUTINE A4
C
C    FIN ACTUATORS MODULE A4
C
      COMMON C(3415)
      EQUIVALENCE (C(0016),DP)
      EQUIVALENCE (C(0020),DQ)
      EQUIVALENCE (C(0024),DR)
      EQUIVALENCE (C(1693),DULD)
```

```
      EQUIVALENCE (C(1696),DUL)
      EQUIVALENCE (C(1697),DURC)
      EQUIVALENCE (C(1700),DUR)
      EQUIVALENCE (C(1701),DLLC)
      EQUIVALENCE (C(1704),DLL)
      EQUIVALENCE (C(1705),DLRC)
      EQUIVALENCE (C(1708),DLR)
      EQUIVALENCE (C(1709),D1D)
      EQUIVALENCE (C(1712),D1)
      EQUIVALENCE (C(1713),D2D)
      EQUIVALENCE (C(1716),D2)
      EQUIVALENCE (C(1717),D3D)
      EQUIVALENCE (C(1720),D3)
      EQUIVALENCE (C(1721),D4D)
      EQUIVALENCE (C(1724),D4)
      EQUIVALENCE (C(1735),WFIN)
      EQUIVALENCE (C(1736),DFIN)
      EQUIVALENCE (C(1737),DGC)
      EQUIVALENCE (C(1738),DRC)
      EQUIVALENCE (C(1739),DPC)
      EQUIVALENCE (C(1740),DMAX)
      EQUIVALENCE (C(1733), DULDEG)
      EQUIVALENCE (C(1734), DULDDG)
C   ACTUATOR INPUT MIXER
      DULC=DGC+DRC+DPC
      DURC=-DGC+DRC+DPC
      DLLC=DGC-DRC+DPC
      DLRC=-DGC-DRC+DPC
C     FIN ANGLE COMMAND LIMITERS
      IF (ABS(DULC).GT.DMAX)  DULC=SIGN(DMAX,DULC)
      IF (ABS(DURC).GT.DMAX)  DURC=SIGN(DMAX,DURC)
      IF (ABS(DLLC).GT.DMAX)  DLLC=SIGN(DMAX,DLLC)
      IF (ABS(DLRC).GT.DMAX)  DLRC=SIGN(DMAX,DLRC)
C   ACTUATOR DYNAMICS
      IF (WFIN.GT.0.0) GO TO 100
      GO TO 200
C     SECOND ORDER ACTUATORS
C     RATE AND DEFLECTION LIMITS
  100 RTLIM=2.9147
C     UPPER-LEFT FIN RESPONSE
      D1D=WFIN*WFIN*(DULC-DUL)-2.*DFIN*WFIN*D1
      IF (ABS(D1).GE.RTLIM)  GO TO 110
      GO TO 120
  110 PROD1=D1D*D1
      IF (PROD1.GE.0.0)  D1D=0.0
  120 DULD=D1
C     UPPER-RT FIN RESPONSE
      D2D=WFIN*WFIN*(DURC-DUR)-2.*DFIN*WFIN*D2
```

```
      IF (ABS(D2).GE.RTLIM)  GO TO 130
      GO TO 140
  130 PROD2=D2D*D2
      IF (PROD2.GE.0.0)  D2D=0.0
  140 DURD=D2
C     LOWER-LEFT FIN RESPONSE
      D3D=WFIN*WFIN*(DLLC-DLL)-2.*DFIN*WFIN*D3
      IF (ABS(D3).GE.RTLIM) GO TO 150
      GO TO 160
  150 PROD3=D3D*D3
      IF (PROD3.GE.0.0)  D3D=0.0
  160 DLLD=D3
C     LOWER-RT FIN RESPONSE
      D4D=WFIN*WFIN*(DLRC-DLR)-2.*DFIN*WFIN*D4
      IF (ABS(D4).GE.RTLIM)  GO TO 170
      GO TO 180
  170 PROD4=D4D*D4
      IF (PROD4.GE.0.0)  D4D=0.0
  180 DLRD=D4
      GO TO 220
C  **** IDEAL ACTUATORS ****
  200 DUL=DULC
      DUR=DURC
      DLL=DLLC
      DLR=DLRC
C  FIN ANGLE LIMITERS
      IF(ABS(DUL).GT.DMAX) DUL=SIGN(DMAX,DUL)
      IF(ABS(DUR).GT.DMAX) DUR=SIGN(DMAX,DUR)
      IF(ABS(DLL).GT.DMAX) DLL=SIGN(DMAX,DLL)
      IF(ABS(DLR).GT.DMAX) DLR=SIGN(DMAX,DLR)
C  PITCH, YAW, ROLL CHANNEL INPUTS
  220 DQ=0.25*(DUL-DUR-DLR+DLL)
      DR=0.25*(DUL+DUR-DLR-DLL)
      DP=0.25*( DUL+DUR+DLR+DLL)
      DULDEG=DUL*57.29578
      DULDDG=DULD*57.29578
      RETURN
      END
C
C
      SUBROUTINE A5I
      RETURN
      END
C
C
      SUBROUTINE A5
      RETURN
      END
```

```
C
C
C
      SUBROUTINE C1I
C
C  INITIALIZATION MODULE FOR LVRJ AUTOPILOT
C
      COMMON C(3415)
      EQUIVALENCE (C(3315),N)
      EQUIVALENCE (C(3316),IPL(1))
      DIMENSION IPL(100)
      IPL(N)=1677
      IPL(N+1)=1689
      IPL(N+2)=1725
      IPL(N+3)=1729
      N=N+4
      RETURN
      END
C
C
C
      SUBROUTINE C1
C
C SUBROUTINE C1-LVRJ
C  THIS AUTOPILOT MODULE IS FOR STV G
C
      COMMON C(3415)
      EQUIVALENCE (C(0581), DYNP)
      EQUIVALENCE (C(0515), PSF)
      EQUIVALENCE (C(0520), AMACH)
      EQUIVALENCE (C(0415),G)
      EQUIVALENCE (C(0507),F)
      EQUIVALENCE (C(0932),T)
      EQUIVALENCE (C(0933), T1)
      EQUIVALENCE (C(0935), T3)
      EQUIVALENCE (C(1636),ANZC)
      EQUIVALENCE (C(1640),ANYC)
      EQUIVALENCE (C(1644),AZM)
      EQUIVALENCE (C(1648),AYM)
      EQUIVALENCE (C(1652),QM)
      EQUIVALENCE (C(1656),RM)
      EQUIVALENCE (C(0980), PM)
      EQUIVALENCE (C(1677),DPCID)
      EQUIVALENCE (C(1680),DPCI)
      EQUIVALENCE (C(1689),P1D)
      EQUIVALENCE (C(1692),P1)
      EQUIVALENCE (C(1725),Z1D)
      EQUIVALENCE (C(1728),Z1)
```

```
      EQUIVALENCE (C(1729),Y10)
      EQUIVALENCE (C(1732),Y1)
      EQUIVALENCE (C(1737),DQC)
      EQUIVALENCE (C(1738),DRC)
      EQUIVALENCE (C(1739),DPC)
      EQUIVALENCE (C(1740), DMAX)
      EQUIVALENCE (C(0165), AKNZ)
      EQUIVALENCE (C(0166), AKQ)
      EQUIVALENCE (C(0167), AKNY)
      EQUIVALENCE (C(0168), AKR)
      EQUIVALENCE (C(0169), AKP)
      AKQI1=7.5
      AKRI1=7.5
      AKPI1=7.5
      AKPI2=10.
      AKQI2=3.0
      AKRI2=3.0
      QCS=-2.75/57.2957795
      QCE=1.45/57.2957795
      IF (DYNP.GT.22.5) GO TO 3
      AKNY=.1
      AKNZ=.1
      IF (DYNP.GT.4.0) GO TO 4
      AKP=.8
      AKR=1.1
      AKQ=1.6
      GO TO 8
    3 AKNY=.3183502-.01573092*DYNP+3.183974E-04*DYNP**2-2.761728E-06*
     1 DYNP**3+7.692308E-09*DYNP**4
      IF (DYNP.GT.45.0) GO TO 5
      AKNZ=.4536143-.02735*DYNP+6.307143E-04*DYNP**2-5.0E-06*DYNP**3
    4 IF (DYNP.GT.35.0) GO TO 6
      AKP=1.087-.1294302*DYNP+.007295*DYNP**2-1.935556E-04*DYNP**3
     1 +1.933333E-06*DYNP**4
      AKR=1.379087-.0819641*DYNP+.00252119*DYNP**2-3.00531E-05*DYNP**3
      AKQ=2.562857-.302156*DYNP+.0177683*DYNP**2-4.99414E-04*DYNP**3
     1 +5.27879E-06*DYNP**4
      GO TO 8
    5 AKNZ=.099625-.001225*DYNP
    6 AKP=.1752143-.00285476*DYNP+1.47619E-05*DYNP**2
      AKR=1.556357-.0665024*DYNP+.00112333*DYNP**2-6.66666E-06*DYNP**3
      AKQ=.4083333-.0036667*DYNP
    8 IF (T.GT.T3) GO TO 1
      IF (AMACH.GT.2.0) GO TO 1
C   SEPARATION AND BOOST AUTOPILOT
      QC=QCS
      IF (T.GE.T1)  QC=QCE
      S1=1.0
```

```
      S2=0.0
      AKQI=AKQI1
      AKRI=AKRI1
      AKPI=AKPI1
      GO TO 16
C   CRUISE AUTOPILOT
    1 CONTINUE
      S1=0.0
      S2=1.0
      AKQI=AKQI2
      AKRI=AKRI2
      AKPI=AKPI2
   16 CONTINUE
C     PITCH AND YAW CHANNELS
      Q1=AKQ*(QM-S1*QC)
      R1=AKR*RM
      ANZM=-AZM/G
      ANYM=AYM/G
      ANZ=ANZC-ANZM
      ANY=ANYC-ANYM
C      POS DQC AND DRC COMMAND NEG TURNING MOMENTS
      DQC1=Q1-S2*AKNZ*ANZ
      Z1D=DQC1
      IF (ABS(DQC).GE.DMAX)  Z1D=0.0
      DQC=DQC1+AKQI*Z1
      IF (ABS(DQC).GE.DMAX)  DQC=SIGN(DMAX,DQC)
      DRC1=R1-S2*AKNY*ANY
      Y1D=DRC1
      IF (ABS(DRC).GE.DMAX)  Y1D=0.0
      DRC=DRC1+AKRI*Y1
      IF (ABS(DRC).GE.DMAX)  DRC=SIGN(DMAX,DRC)
    2 CONTINUE
C      ROLL CHANNEL
      P1D=AKPI*PM
C      LAG COMPENSATOR
      OMG1=.1
      OMG2=.01
      DPCD=-AKP*(PM+P1)*OMG2/OMG1
      DPCID=(OMG1-OMG2)*DPCD-OMG2*DPCI
      DPC=DPCI+DPCD
      IF (ABS(DPC).GE.DMAX)  DPC=SIGN(DMAX,DPC)
      RETURN
      END
C
C
C
      SUBROUTINE C2I
C
```

```
      DIMENSION IPL(100)
      COMMON C(3415)
      EQUIVALENCE (C(0507),H)
      EQUIVALENCE (C(3315),N)
      EQUIVALENCE (C(3316),IPL(1))
      IPL(N)=1633
      IPL(N+1)=1637
      N=N+2
      HNOW=H
      RETURN
      END
C
C
C
      SUBROUTINE C2
C
C   GUIDANCE COMMAND MODULE
C
      COMMON C(3415)
      EQUIVALENCE (C(0256), A33)
      EQUIVALENCE (C(0286), VXTP)
      EQUIVALENCE (C(0294), VYTP)
      EQUIVALENCE (C(0302), VZTP)
      EQUIVALENCE (C(337), CMGYC)
      EQUIVALENCE (C(338), CMGZC)
      EQUIVALENCE (C(0317), FLGT)
      EQUIVALENCE (C(0339), XMA)
      EQUIVALENCE (C(0340), YMA)
      EQUIVALENCE (C(0341), ZMA)
      EQUIVALENCE (C(0520), AMACH)
      EQUIVALENCE (C(0500),HCC)
      EQUIVALENCE (C(0501),HREF)
      EQUIVALENCE (C(0502),HD)
      EQUIVALENCE (C(0507),H)
      EQUIVALENCE (C(0508), GD)
      EQUIVALENCE (C(0515),PSF)
      EQUIVALENCE (C(0527),GAMMAV)
      EQUIVALENCE (C(0528), VT)
      EQUIVALENCE (C(0531),VH)
      EQUIVALENCE (C(0581), DYNP)
      EQUIVALENCE (C(0582),AKG)
      EQUIVALENCE (C(0932),T)
      EQUIVALENCE (C(0933),T1)
      EQUIVALENCE (C(0935),T3)
      EQUIVALENCE (C(0937),T5)
      EQUIVALENCE (C(942),TCC)
      EQUIVALENCE (C(0944),TLD)
      EQUIVALENCE (C(0945),TFC)
```

```
      EQUIVALENCE (C(1633),ANZCD)
      EQLIVALENCE (C(1636),ANZC)
      EQLIVALENCE (C(1637),ANYCD)
      EQUIVALENCE (C(1640),ANYC)
      EQUI VALENCE (C(1750), WF1)
      DATA RCCN/36500./
      DYNP=GD/144.
C   ZERC MODE CCNTROL SWITCHES
      S4=0.0
      S5=C.C
      S6=C.C
      S8=0.0
      IF (T.GE.T3) GO TC 1
C   SEPARATICN,BCCST PHASE
      IF(AMACH.GE.2.0) GC TC 1
      GO TC 1CC
C   ZERC G TRAJECTCRY
    1 IF(T.GE.T5) GO TO 2
      GO TC 1CC
C   LEVEL FLIGHT
    2 IF(T.GE.TDC) GO TO 5
      S4=1.0
      S5=1.0
      GO TC 1CC
C   DIVE,CLIME
    5 IF(T.GE.TLD) GO TO 4
      HDC1=HCC
    7 S4=1.0
      S5=1.C
      S8=1.C
      GO TC 100
C   ALTCMATIC LETDCWN TO HREF
    4 HORIZ=SGRT(XMA**2+YMA**2)
      D1=1.975*VH+RCCN-HCRIZ
      IF (D1.GE.C.C) GO TC 6
      S4=1.0
      S5=1.0
      S6=1.0
      GO TC 100
C     TERMINAL DIVE
    6 W3=(ZMA*V)TP-XMA*VZTP)/(XMA*VXTP+ZMA*VZTP)
      ANZC1=-2.*2900.*W3/32.172+A33
      IF (FLGT.GT.0.0) GC TC 8
      GO TC 1C8
C     TERMINAL HCMING
    8 ANZC1=AKG*VT*OMGYC/32.174
      GO TC 1C8
  100 CCNTINLE
```

```
C   ***** VERTICAL CHANNEL *****
C   HERR LIMITER
       HERR1=S6*(H-HREF)
       HERR2=0.5*HERR1
       IF (ABS(HERR1).GT.800.)  HERR2=SIGN(400.,HERR1)
       ANZC1=.0333*(S8*HDC1-S4*(HD+HERR2))+S5*A33
C   NZ LIMITER
       IF(ANZC1) 108,107,108
  108  AZMAX=.35*(DYNP-5.714)
       IF (DYNP.LE.30.0) AZMAX=8.5*DYNP/30.
       AZMAX=AMIN1(AZMAX,12.0)
       IF (ABS(ANZC1).GE.AZMAX)  ANZC1=SIGN(AZMAX,ANZC1)
  107  CONTINUE
C   ***** LATERAL CHANNEL *****
       ANYC1=0.
       IF (T.LT.T5) GO TO 210
       IF (FLGT.GT.0.0) GO TO 200
C     CROSS-PRODUCT MIDCOURSE GUIDANCE
       CPROD=(YMA*VXTP-XMA*VYTP)/(XMA*VXTP+YMA*VYTP)
       ANYC1=2900.*CPROD/32.172
       GO TO 205
C      TERMINAL HOMING
  200  ANYC1=AKG*VT*OMGZC/32.172
C     NY LIMITER
  205  IF (ANYC1) 208,207,208
  208  AYMAX=8.0*(DYNP-11.25)/22.5
       IF (DYNP.LE.22.5) AYMAX=4.0*DYNP/22.5
       AYMAX=AMIN1(AYMAX,12.0)
       IF (ABS(ANYC1).GT.AYMAX)  ANYC1=SIGN(AYMAX,ANYC1)
  207  CONTINUE
C     ELLIPTICAL LIMITING
       DENOM=SQRT((AZMAX*ANYC1)**2+(AYMAX*ANZC1)**2)
       IF (DENOM.LE.0.0)  GO TO 210
       AZLIM=AZMAX*AYMAX*ANZC1/DENOM
       IF (ABS(ANZC1).GE.ABS(AZLIM))  ANZC1=AZLIM
       AYLIM=AZMAX*AYMAX*ANYC1/DENOM
       IF (ABS(ANYC1).GE.ABS(AYLIM))  ANYC1=AYLIM
C LATERAL COMMAND FILTER
  210  ANYCD=WF1*(ANYC1-ANYC)
C     VERTICAL COMMAND FILTER
       ANZCD=WF1*(ANZC1-ANZC)
       RETURN
       END
C
C
       SUBROUTINE C3I
       RETURN
       END
```

```
C
C
      SUBRCLTINE C3
      RETURN
      ENC
C
C
      SUBROUTINE C4I
      RETURN
      END
C
C
      SUBRCLTINE C4
      RETURN
      ENC
C
C
      SUBRCUTINE C5I
      RETURN
      END
C
C
      SUBRCUTINE C5
      RETURN
      END
C
C
      SUERCUTINE C6I
      RETURN
      END
C
C
      SUBRCLTINE C6
      RETURN
      END
C
C
      SUBRCLTINE C7I
      RETURN
      END
C
C
      SUBRCUTINE C7
      RETURN
      END
C
C
      SUERCLTINE C8I
```

```
      RETURN
      ENC
C
C
      SUBRCUTINE C8
      RETURN
      ENC
C
C
      SUBRCLTINE C9I
      RETURN
      ENC
C
C
      SUBRCUTINE C9
      RETURN
      END
C
C
      SUBRCLTINE C10I
      RETURN
      ENC
C
C
      SUBRCLTINE C10
      RETURN
      ENC
C
C
C
      SUBRCUTINE C1I                                                    C1IA003C
C
C     TRANSLATICNAL DYNAMICS INITIALIZATION MODULE D1AB                 C1IA001C
C     FOR USE WITH MODULE C1A CR D1B                                    C1IA0020
C
      DIMENSICN  IPL (100)                                              C1IA007C
      CCMMCN C(3415)                                                    C1IA0040
      ECLIVALENCE  (C(3315) , N      )                                  C1IA005C
      EQUIVALENCE (C(3316),IPL(1))
      IPL(N) = 283                                                      C1IA0100
      IPL(N+1) = 291                                                    C1IA011C
      IPL(N+2) = 299                                                    C1IA012C
      IPL(N+3) = 287                                                    C1IA013C
      IPL(N+4) = 295                                                    C1IA014C
      IPL(N+5) = 303                                                    C1IA0150
      N = N+6                                                           C1IA016C
      RETURN                                                            C1IA0170
      ENC                                                               C1IA0200
```

```
C
C
C
      SUBROUTINE D1
C
C     TRANSLATIONAL DYNAMICS MODULE D1B - BODY AXES
C
      COMMON C(3415)
      EQUIVALENCE  (C(0073) , TXBA    )
      EQUIVALENCE  (C(0074) , TYBA    )
      EQUIVALENCE  (C(0075) , TZBA    )
      EQUIVALENCE  (C(0086) , WE      )
      EQUIVALENCE (C(0112), FEJ)
      EQUIVALENCE  (C(0128) , FXBA    )
      EQUIVALENCE  (C(0129) , FYBA    )
      EQUIVALENCE  (C(0130) , FZBA    )
      EQUIVALENCE (C(0224),A11   )
      EQUIVALENCE (C(0228),A12   )
      EQUIVALENCE (C(0232),A13   )
      EQUIVALENCE (C(0236),A21   )
      EQUIVALENCE (C(0240),A22   )
      EQUIVALENCE (C(0244),A23   )
      EQUIVALENCE (C(0248),A31   )
      EQUIVALENCE (C(0252),A32   )
      EQUIVALENCE (C(0256),A33   )
      EQUIVALENCE  (C(0282) , AG      )
      EQUIVALENCE  (C(0283) , VXDTP   )
      EQUIVALENCE  (C(0286) , VXTP    )
      EQUIVALENCE  (C(0287) , XDTP    )
      EQUIVALENCE  (C(0290) , XTP     )
      EQUIVALENCE  (C(0291) , VYDTP   )
      EQUIVALENCE  (C(0294) , VYTP    )
      EQUIVALENCE  (C(0295) , YDTP    )
      EQUIVALENCE  (C(0298) , YTP     )
      EQUIVALENCE  (C(0299) , VZDTP   )
      EQUIVALENCE  (C(0302) , VZTP    )
      EQUIVALENCE  (C(0303) , ZDTP    )
      EQUIVALENCE  (C(0306) , ZTP     )
      EQUIVALENCE  (C(0411) , GCX     )
      EQUIVALENCE  (C(0412) , GCY     )
      EQUIVALENCE  (C(0413) , GCZ     )
      EQUIVALENCE  (C(0710) , TAXBA   )
      EQUIVALENCE  (C(0711) , TAYBA   )
      EQUIVALENCE  (C(0712) , TAZBA   )
      EQUIVALENCE  (C(0713) , TAX)
      EQUIVALENCE (C(0714)  , TAY)
      EQUIVALENCE  (C(0715)  , TAZ)
      AGWE = AG/WE
```

```
C     TOTAL ACCELERATION DUE TO AERODYNAMIC FORCES AND THRUST FORCES
      TAXBA = AGWE*(FXBA + TXBA)
      TAYBA = AGWE*(FYBA + TYBA)
      TAZBA= AGWE*(FZBA+TZBA+FEJ)
C     RESOLVE FROM BODY AXES TO TANGENT PLANE
      TAX = A11*TAXBA + A21*TAYBA + A31*TAZBA
      TAY = A12*TAXBA + A22*TAYBA + A32*TAZBA
      TAZ = A13*TAXBA + A23*TAYBA + A33*TAZBA
C     INTEGRATE ACCELERATIONS DUE TO AERODYNAMICS, THRUST, GRAVITY,
C     AND CORIOLIS
      VXDTP = TAX + GCX
      VYDTP = TAY + GCY
      VZDTP = TAZ + GCZ
C     INTEGRATE VELOCITY
      XDTP = VXTP
      YDTP = VYTP
      ZDTP = VZTP
      RETURN
      END
C
C
C
      SUBROUTINE D2I
C
C     ROTATIONAL DYNAMICS INITIALIZATION MODULE D2IEUL
C     FOR USE WITH MODULE D2F OR D2SA
C
      COMMON C(3415)
      EQUIVALENCE (C(224) ,A11    )
      EQUIVALENCE (C(228) ,A12    )
      EQUIVALENCE (C(232) ,A13    )
      EQUIVALENCE (C(236) ,A21    )
      EQUIVALENCE (C(240) ,A22    )
      EQUIVALENCE (C(244) ,A23    )
      EQUIVALENCE (C(248) ,A31    )
      EQUIVALENCE (C(252) ,A32    )
      EQUIVALENCE (C(256) ,A33    )
      EQUIVALENCE (C(2901),ROLLO )
      EQUIVALENCE (C(2902),PITCHO)
      EQUIVALENCE (C(2903),YAWO   )
      EQUIVALENCE  (C(3315) , N     )
      DIMENSION  IPL (100)
      SP=SIN(ROLLO)
      CT=COS(PITCHO)
      ST=SIN(PITCHO)
      EQUIVALENCE  (C(3316) , IPL(1))
      SS = SIN(YAWO)
      CS=COS(YAWO)
```

```
      CP = COS(ROLLO)
      A11= CS*CT
      A12= SS*CT
      A13= -ST
      A21= -SS*CP + CS*ST*SP
      A22= CS*CP +SS*ST*SP
      A23= CT*SP
      A31= CS*ST*CP + SS*SP
      A32= SS*ST*CP - CS*SP
      A33= CT*CP
      IPL(N) = 209
      IPL(N+1) = 213
      IPL(N+2) = 217
      IPL(N+3) = 221
      IPL(N+4) = 225
      IPL(N+5) = 229
      IPL(N+6) = 233
      IPL(N+7) = 237
      IPL(N+8) = 241
      IPL(N+9) = 245
      IPL(N+10) = 249
      IPL(N+11) = 253
      N = N+12
      RETURN
      END
C
C
C
      SUBROUTINE D2
C
C     ROTATIONAL DYNAMICS MODULE D2PA- PRINCIPAL AXES
C
      COMMON C(3415)
      COMMON/APPLE/TM1(7),TM2(15),TM3(14),TM4(5),TETA1(7),TETA2(7),
     1TETA3(6),TXI1(2),TXI2(10),TXI3(5),TDELT(4),TH1(3),TH2(2),
     2TCZBC(7,2,7),TDCZP(14,7),TCYBC(7,10,6),TCMBC(7,5,7),TDCMF(14,7),
     3TCDB(15,2),TCDC(15,2),TCAD2(15),TCNBC(7,10,6),TCMD1(15,4),
     4TCMD2(5,4),TDCMD(15),TDCMDA(15),TPMD(14,3),TCMQ(15),TPQ(14,3),
     5TCLBC(7,10,6),TCLD(15),TPLD(14,3),TCLP(15),TPP(14,3),TDCYSP(3),
     LTDCZSP(3),TDCMSP(3),TDCNSP(3),TH3(3),TFEJ(13),TTEJ(13)
      EQUIVALENCE (C(0109), FLGSEP)
      EQUIVALENCE (C(0112), FEJ)
      EQUIVALENCE  (C(0131) , CLBA    )
      EQUIVALENCE  (C(0132) , CMBA    )
      EQUIVALENCE  (C(0133) , CNBA    )
      EQUIVALENCE (C(0136), CG)
      EQUIVALENCE  (C(0150) , CLT     )
      EQUIVALENCE  (C(0151) , CMT     )
```

```
      EQUIVALENCE  (C(0152) , CNT     )
      EQUIVALENCE  (C(0201) , A       )
      EQUIVALENCE  (C(0202) , B       )
      EQUIVALENCE  (C(0209) , PDBA    )
      EQUIVALENCE  (C(0203) , G       )
      EQUIVALENCE  (C(0212) , PBA     )
      EQUIVALENCE  (C(0213) , QDBA    )
      EQUIVALENCE  (C(0216) , QBA     )
      EQUIVALENCE  (C(0217) , RDBA    )
      EQUIVALENCE  (C(0220) , RBA     )
      EQUIVALENCE  (C(0221) , AD11    )
      EQUIVALENCE  (C(0224) , A11     )
      EQUIVALENCE  (C(0228) , A12     )
      EQUIVALENCE  (C(0225) , AD12    )
      EQUIVALENCE  (C(0229) , AD13    )
      EQUIVALENCE  (C(0232) , A13     )
      EQUIVALENCE  (C(0236) , A21     )
      EQUIVALENCE  (C(0237) , AD22    )
      EQUIVALENCE  (C(0233) , AD21    )
      EQUIVALENCE  (C(0240) , A22     )
      EQUIVALENCE  (C(0241) , AD23    )
      EQUIVALENCE  (C(0245) , AD31    )
      EQUIVALENCE  (C(0244) , A23     )
      EQUIVALENCE  (C(0248) , A31     )
      EQUIVALENCE  (C(0249) , AD32    )
      EQUIVALENCE  (C(0252) , A32     )
      EQUIVALENCE (C(0253), AD33)
      EQUIVALENCE (C(0256), A33 )
      EQUIVALENCE (C(0932), T  )
      EQUIVALENCE (C(0933), T1)
      FEJ=0.0
      XEJ=10.585
      IF (T1.LE.0.0)  FLGSEP=0.0
      YEJ=-.01
      IF (FLGSEP.LE.0.) GO TO 10
      IF (T.GE.0.1) GO TO 10
C        EJECTION FORCE
      FEJ=CDLI(T,TTEJ,TFEJ,13)
C     ADD AERODYNAMIC,THRUST,AND EJECTION MOMENTS
   10 TLBA=CLBA+CLT+FEJ*YEJ
      TMBA=CMBA+CMT+FEJ*(XEJ-CG)
      TNBA = CNBA + CNT
C     INTEGRATE BODY ANGULAR RATES
      PDBA =  (TLBA  + (B-G)*QBA*RBA)/A
      QDBA =  (TMBA  + (G-A)*RBA*PBA)/B
      RDBA =  (TNBA  + (A-B)*PBA*QBA)/G
C     INTEGRATE ATTITUDE DIRECTION COSINES
      AD11=A21*RBA-A31*QBA
```

```
      AD22=A32*PBA-A12*RBA
      AD21=A31*PBA-A11*RBA
      AD13=A23*RBA-A33*QBA
      AD12=A22*RBA-A32*QBA
      AD33=A13*QBA-A23*PBA
      AD32=A12*QBA-A22*PBA
      AD31=A11*QBA-A21*PBA
      AD23=A33*PBA-A13*RBA
      RETURN
      END
C
C
      SUBROUTINE D3I
      RETURN
      END
C
C
      SUBROUTINE D3
      RETURN
      END
C
C
      SUBROUTINE D4I
      RETURN
      END
C
C
      SUBROUTINE D4
      RETURN
      END
C
C
      SUBROUTINE D5I
      RETURN
      END
C
C
      SUBROUTINE D5
      RETURN
      END
C
C
C
      SUBROUTINE G1I
C
C     GRAVITATIONAL AND CORIOLIS ACCELERATION INITIALIZATION MODULE G1IC
C
      COMMON C(3415)
```

```
      EQUIVALENCE  (C(0402) , ZS          )
      EQUIVALENCE  (C(0403) , GM          )
      EQUIVALENCE  (C(0405) , ER          )
      EQUIVALENCE  (C(0406) , ALPO        )
      EQUIVALENCE  (C(0407) , CLAMO       )
      EQUIVALENCE  (C(0408) , CMEGX       )
      EQUIVALENCE  (C(0409) , CMEGY       )
      EQUIVALENCE  (C(0410) , CMEGZ       )
      EQUIVALENCE  (C(0414) , HO          )
      EQUIVALENCE  (C(0415) , GO          )
      EQUIVALENCE  (C(0503) , FE          )
      ZS = RE + HO
      GM = GO*ZS*ZS
      RT = ER + ER
      CMEGZ = -RT*SIN(CLAMO)
      RT = RT*COS(CLAMO)
      CMEGY = -RT*SIN(ALPO)
      CMEGX = RT*COS(ALPO)
      RETURN
      END
C
C
C
      SUBROUTINE G1
C
C     GRAVITATIONAL AND CORIOLIS ACCELERATION MODULE GIC
C
      COMMON C(3415)
      EQUIVALENCE  (C(0286) , VXTP    )
      EQUIVALENCE  (C(0294) , VYTP    )
      EQUIVALENCE  (C(0302) , VZTP    )
      EQUIVALENCE  (C(0290) , XTP         )
      EQUIVALENCE  (C(0298) , YTP         )
      EQUIVALENCE  (C(0306) , ZTP         )
      EQUIVALENCE  (C(0401) , R           )
      EQUIVALENCE  (C(0402) , ZS          )
      EQUIVALENCE  (C(0403), GM)
      EQUIVALENCE  (C(0404) , GZRO        )
      EQUIVALENCE  (C(0408) , CMEGX       )
      EQUIVALENCE  (C(0409) , CMEGY       )
      EQUIVALENCE  (C(0410) , CMEGZ       )
      EQUIVALENCE  (C(0411) , GCX         )
      EQUIVALENCE  (C(0412) , GCY         )
      EQUIVALENCE  (C(0413) , GCZ         )
      EQUIVALENCE  (C(0414) , HO          )
      EQUIVALENCE  (C(0415) , GO          )
      EQUIVALENCE (C(0502),HD)
      EQUIVALENCE  (C(0503) , RE          )
```

```
      EQUIVALENCE  (C(0507) , H          )
      EQUIVALENCE  (C(0507), H )
C     IF GZRO = 0, FLAT-EARTH GRAVITATIONAL FIELD
      IF (GZRO .EQ. 1.0) GO TO 1
C     COMPUTE FLAT-EARTH GRAVITATIONAL ACCELERATION
      GCX = 0.
      GCY = 0.
      GCZ = GO
      H = -ZTP +HO
      HD=-VZTP
      RETURN
C     IF GZRO = 1, SPHERICAL GRAVITATIONAL FIELD
    1 R = SQRT(XTP*XTP + YTP*YTP + (ZTP-ZS)*(ZTP-ZS))
      HD=(XTP*VXTP+YTP*VYTP+(ZTP-ZS)*VZTP)/R
      H = R - RE
C     COMPUTE SPHERICAL GRAVITATIONAL ACCELERATION
      GMR = -GM/(R*R*R)
      GX = GMR*XTP
      GY = GMR*YTP
      GZ = GMR*(ZTP-ZS)
C     ADD CORIOLIS ACCELERATION
      GCX = GX + OMEGZ*VYTP - OMEGY*VZTP
      GCY = GY + OMEGX*VZTP - OMEGZ*VXTP
      GCZ = GZ + OMEGY*VXTP - OMEGX*VYTP
      RETURN
      END
C
C
      SUBROUTINE G2I
      RETURN
      END
C
C
      SUBROUTINE G2
      RETURN
      END
C
C
C
      SUBROUTINE G3I
C
      COMMON C(3415)
      EQUIVALENCE (C(0208) , TSA )
      EQUIVALENCE (C(0257) , CTS )
      EQUIVALENCE (C(0258) , STS )
      EQUIVALENCE (C(0306), ZTP)
      EQUIVALENCE (C(0414), HO)
      EQUIVALENCE (C(0507), H)
```

```
      EQUIVALENCE (C(0515), FSF)
      EQUIVALENCE (C(0529), VAT)
      EQUIVALENCE (C(0551), RHOH)
      EQUIVALENCE (C(0561), VAH)
      H=HC-ZTP
      ALT=H/3.280839895
      VEL=VAT/3.280839895
      CALL AIR (ALT,VEL,-1,P,T,SON,DEN,Q,G,1,2)
      CTS = COS(TSA)
      STS = SIN(TSA)
      RETURN
      END
C
C
C
      SUBROUTINE G3
C
C     AIR DATA MODULE G3
C
      COMMON C(3415)
      EQUIVALENCE  (C(0224) , A11          )
      EQUIVALENCE  (C(0228) , A12          )
      EQUIVALENCE  (C(0232) , A13          )
      EQUIVALENCE  (C(0236) , A21          )
      EQUIVALENCE  (C(0240) , A22          )
      EQUIVALENCE  (C(0244) , A23          )
      EQUIVALENCE  (C(0248) , A31          )
      EQUIVALENCE  (C(0252) , A32          )
      EQUIVALENCE  (C(0256) , A33          )
      EQUIVALENCE  (C(0257) , CTS          )
      EQUIVALENCE  (C(0258) , STS          )
      EQUIVALENCE  (C(0282) , AG           )
      EQUIVALENCE  (C(0286) , VXTP         )
      EQUIVALENCE  (C(0294) , VYTP         )
      EQUIVALENCE  (C(0302) , VZTP         )
      EQUIVALENCE  (C(0451) , TWXTP        )
      EQUIVALENCE  (C(0452) , TWYTP        )
      EQUIVALENCE  (C(0453) , TWZTP        )
      EQUIVALENCE  (C(0504) , VATX         )
      EQUIVALENCE  (C(0505) , VATY         )
      EQUIVALENCE  (C(0506) , VATZ         )
      EQUIVALENCE  (C(0507) , H            )
      EQUIVALENCE  (C(0508) , CD           )
      EQUIVALENCE  (C(0509) , UBA          )
      EQUIVALENCE  (C(0510) , VBA          )
      EQUIVALENCE  (C(0511) , WBA          )
      EQUIVALENCE  (C(0512) , USA          )
      EQUIVALENCE  (C(0513) , VSA          )
```

```
      EQUIVALENCE  (C(0514) , WSA        )
      EQUIVALENCE (C(0515), PSF)
      EQUIVALENCE  (C(0518) , ASA        )
      EQUIVALENCE  (C(0519) , ESA        )
      EQUIVALENCE  (C(0520) , AMACH      )
      EQUIVALENCE  (C(0529) , VAT        )
      EQUIVALENCE (C(0551) , RHOH)
      EQUIVALENCE (C(0561) , VAH)
C     VELOCITY WITH RESPECT TO AIR MASS
      VATX = VXTP - TWXTP
      VATY = VYTP - TWYTP
      VATZ = VZTP - TWZTP
      VATSQ = VATX*VATX + VATY*VATY + VATZ*VATZ
      VAT = SQRT(VATSQ)
      ALT=H/3.280839895
      VEL=VAT/3.280839895
      CALL AIR (ALT,VEL,1,P,T,SON,DEN,Q,G,1,2)
      PSF=.020885434*P
      RHOH=.062427961*DEN
      QD=.020885434*Q
      VAH=3.280839895*SON
      AMACH = VAT/VAH
C    ORTHOGONALIZE DIRECTION COSINES
      DAN=SQRT(A11**2+A12**2+A13**2)
      E11=A11/DAN
      E12=A12/DAN
      E13=A13/DAN
      D=E11*A21+E12*A22+E13*A23
      V21=A21-D*E11
      V22=A22-D*E12
      V23=A23-D*E13
      DON=SQRT(V21**2+V22**2+V23**2)
      E21=V21/DON
      E22=V22/DON
      E23=V23/DON
      C1=E11*A31+E12*A32+E13*A33
      C2=E21*A31+E22*A32+E23*A33
      V31=A31-C1*E11-C2*E21
      V32=A32-C1*E12-C2*E22
      V33=A33-C1*E13-C2*E23
      DAP=SQRT(V31**2+V32**2+V33**2)
      E31=V31/DAP
      E32=V32/DAP
      E33=V33/DAP
      A11=E11
      A12=E12
      A13=E13
      A21=E21
```

```
      A22=E22
      A23=E23
      A31=E31
      A32=E32
      A33=E33
C     VELOCITY IN BODY AXES
      UBA=A11*VATX+A12*VATY+A13*VATZ
      VBA=A21*VATX+A22*VATY+A23*VATZ
      WBA = A31*VATX + A32*VATY + A33*VATZ
C     VELOCITY IN STABILITY AXES
      USA=CTS*UBA+STS*WBA                                             TXY01260
      VSA=VBA                                                         TXY01270
      WSA=-STS*UBA+CTS*WBA                                            TXY01280
C     ANGLE OF ATTACK AND SIDESLIP
      ASA = ATAN(WSA/USA)
      BSA = ARSIN(VSA/SQRT(USA*USA + VSA*VSA + WSA*WSA))
      RETURN
      END
C
C
      SUBROUTINE G4I
      RETURN
      END
C
C
      SUBROUTINE G4
      RETURN
      END
C
C
C
      SUBROUTINE G5I
C
C   COORDINATE CONVERSION INITIALIZATION MODULE
C
      COMMON C(3415)
      EQUIVALENCE  (C(0557),CTPI11)
      EQUIVALENCE  (C(0558),CTPI12)
      EQUIVALENCE  (C(0559),CTPI13)
      EQUIVALENCE  (C(0560),CTPI21)
      EQUIVALENCE  (C(0562),CTPI22)
      EQUIVALENCE  (C(0563),CTPI23)
      EQUIVALENCE  (C(0564),CTPI31)
      EQUIVALENCE  (C(0565),CTPI32)
      EQUIVALENCE  (C(0566),CTPI33)
      EQUIVALENCE  (C(0576),ALAT)
      EQUIVALENCE  (C(0578),AZ)
      AZ = AZ*.01745329
```

```
      ALAT = ALAT*.01745329
      CTPI11 =-COS(AZ)*SIN(ALAT)
      CTPI12 =   SIN(ALAT)*SIN(AZ)
      CTPI13 = -COS(ALAT)
      CTPI21 = SIN(AZ)
      CTPI22 =   COS(AZ)
      CTPI23 = 0.0
      CTPI31 =   COS(ALAT)*COS(AZ)
      CTPI32 =-COS(ALAT)*SIN(AZ)
      CTPI33 = -SIN(ALAT)
      RETURN
      END
C
C
      SUBROUTINE G5
C
C     COORDINATE CONVERSION MODULE G5
C
      COMMON C(3415)
      EQUIVALENCE  (C(0224),CTPB11)
      EQUIVALENCE  (C(0228),CTPB12)
      EQUIVALENCE  (C(0232),CTPB13)
      EQUIVALENCE  (C(0236),CTPB21)
      EQUIVALENCE  (C(0240),CTPB22)
      EQUIVALENCE  (C(0244),CTPB23)
      EQUIVALENCE  (C(0248),CTPB31)
      EQUIVALENCE  (C(0252),CTPB32)
      EQUIVALENCE  (C(0256),CTPB33)
      EQUIVALENCE  (C(0557),CTPI11)
      EQUIVALENCE  (C(0558),CTPI12)
      EQUIVALENCE  (C(0559),CTPI13)
      EQUIVALENCE  (C(0560),CTPI21)
      EQUIVALENCE  (C(0562),CTPI22)
      EQUIVALENCE  (C(0563),CTPI23)
      EQUIVALENCE  (C(0564),CTPI31)
      EQUIVALENCE  (C(0565),CTPI32)
      EQUIVALENCE  (C(0566),CTPI33)
      EQUIVALENCE  (C(0567),CBI11)
      EQUIVALENCE  (C(0568),CBI12)
      EQUIVALENCE  (C(0569),CBI13)
      EQUIVALENCE  (C(0569),CBI13)
      EQUIVALENCE  (C(0570),CBI21)
      EQUIVALENCE  (C(0571),CBI22)
      EQUIVALENCE  (C(0572),CBI23)
      EQUIVALENCE  (C(0573),CBI31)
      EQUIVALENCE  (C(0574),CBI32)
      EQUIVALENCE  (C(0575),CBI33)
      EQUIVALENCE  (C(0710),TAXAA)
```

```
      EQUIVALENCE  (C(0711),TAYAA)
      EQUIVALENCE  (C(0712),TAZAA)
      EQUIVALENCE  (C(0286), VXTP)
      EQUIVALENCE  (C(0294), VYTP)
      EQUIVALENCE  (C(0302), VZTP)
      EQUIVALENCE  (C(0290) , XTP        )
      EQUIVALENCE  (C(0298) , YTP        )
      EQUIVALENCE  (C(0306) , ZTP        )
      EQUIVALENCE  (C(0521) , THET       )
      EQUIVALENCE  (C(0554),AXECI)
      EQUIVALENCE  (C(0555),AYECI)
      EQUIVALENCE  (C(0556),AZECI)
      EQUIVALENCE  (C(0577),VXECI)
      EQUIVALENCE  (C(0552),VYECI)
      EQUIVALENCE  (C(0553),VZECI)
      EQUIVALENCE  (C(0547),XECI)
      EQUIVALENCE  (C(0548),YECI)
      EQUIVALENCE  (C(0549),ZECI)
      EQUIVALENCE  (C(0402),ZS)
      EQUIVALENCE  (C(0522) , PSI        )
      EQUIVALENCE  (C(0523) , PHI        )
      EQUIVALENCE  (C(0524) , BEAR       )
      EQUIVALENCE  (C(0525) , ELEV       )
      EQUIVALENCE  (C(0526) , SLANT      )
      EQUIVALENCE  (C(0527), GAMMAV)
      EQUIVALENCE  (C(0528), VGS)
      EQUIVALENCE  (C(0531), VH)
      EQUIVALENCE  (C(0532), GAMMAH)
C MATRIX A = MATRIX CTPB
C     HEADING, PITCH, ROLL
      PSI = ATAN2(CTPB12,CTPB11)
      THET = -ARSIN(CTPB13)
      PHI = ATAN2(CTPB23,CTPB33)
C     FLIGHT PATH
      VH= SQRT(VXTP*VXTP + VYTP*VYTP)
      GAMMAH = ATAN2(VYTP,VXTP)
      GAMMAV = ATAN (-VZTP/VH)
C     SLANT RANGE AND TOTAL VELOCITY
      SLANT = SQRT(XTP*XTP + YTP*YTP + ZTP*ZTP)
      VGS = SQRT(VXTP*VXTP + VYTP*VYTP + VZTP*VZTP)
C     BEARING AND ELEVATION
      IF(YTP) 3,1,3
    1 IF(XTP) 3,2,3
    2 BEAR=0.0
      GO TO 4
    3 BEAR=ATAN2(YTP,XTP)
    4 CONTINUE
      IF(XTP.EQ.0.0 .AND. YTP.EQ.0.0) GO TO 50
```

```
      ELEV = ATAN (-ZTP/SQRT(XTP*XTP + YTP*YTP))
      GO TO 60
   50 ELEV=0.0
   60 CONTINUE
C   CEI = CTPI*CETP
      CBI11 = CTPI11*CTPB11 + CTPI12*CTPB12 + CTPI13*CTPB13
      CBI12 = CTPI11*CTPB21 + CTPI12*CTPB22 + CTPI13*CTPB23
      CBI13 = CTPI11*CTPB31 + CTPI12*CTPB32 + CTPI13*CTPB33
      CBI21 = CTPI21*CTPB11 + CTPI22*CTPB12 + CTPI23*CTPB13
      CBI22 = CTPI21*CTPB21 + CTPI22*CTPB22 + CTPI23*CTPB23
      CBI23 = CTPI21*CTPB31 + CTPI22*CTPB32 + CTPI23*CTPB33
      CBI31 = CTPI31*CTPB11 + CTPI32*CTPB12 + CTPI33*CTPB13
      CBI32 = CTPI31*CTPB21 + CTPI32*CTPB22 + CTPI33*CTPB23
      CBI33 = CTPI31*CTPB31 + CTPI32*CTPB32 + CTPI33*CTPB33
C   DETERMINE ACCELERATION, VELOCITY AND POSITION IN ECI SYSTEM
      AXECI = CTPI11*TAXAA + CTPI12*TAYAA + CTPI13*TAZAA
      AYECI = CTPI21*TAXAA + CTPI22*TAYAA + CTPI23*TAZAA
      AZECI = CTPI31*TAXAA + CTPI32*TAYAA + CTPI33*TAZAA
      VXECI = CTPI11*VXTP + CTPI12*VYTP + CTPI13*VZTP
      VYECI = CTPI21*VXTP + CTPI22*VYTP + CTPI23*VZTP
      VZECI = CTPI31*VXTP + CTPI32*VYTP + CTPI33*VZTP
      XECI  = CTPI11*XTP + CTPI12*YTP + CTPI13*(ZTP - ZS)
      YECI  = CTPI21*XTP + CTPI22*YTP + CTPI23*(ZTP - ZS)
      ZECI  = CTPI31*XTP + CTPI32*YTP + CTPI33*(ZTP - ZS)
      RETURN
      END
C
C
      SUBROUTINE G6I
      RETURN
      END
C
C
      SUBROUTINE G6
      RETURN
      END
C
C
      SUBROUTINE S1I
C
C     HOMING SEEKER INITIALIZATION MODULE  S1I
C
      COMMON C(3415)
      DIMENSION  IPL(100)
      EQUIVALENCE (C(0317), FLGT)
      EQUIVALENCE (C(0347), FLGTS)
      EQUIVALENCE (C(3315), N )
      EQUIVALENCE (C(3316), IPL(1))
```

```
      IPL(N)=262
      IPL(N+1)=266
      IPL(N+2)=270
      IPL(N+3)=274
      IPL(N+4)=322
      IPL(N+5)=326
      IPL(N+6)=416
      IPL(N+7)=420
      IPL(N+8)=424
      IPL(N+9)=428
      N=N+10
      FLGT=C.C
      FLGTS=C.0
      RETURN
      END
C
C
C
      SUBRCUTINE S1
C
C      HCMING SEEKER MODULE  S1
C
      CCMMCN C(3415)
      EQUIVALENCE (C(187), CNCIS1)
      EQUIVALENCE (C(197), CNOIS2)
      EQUIVALENCE  (C(212) , P)
      EQUIVALENCE  (C(216) , Q)
      EQUIVALENCE  (C(220) , R)
      EQUIVALENCE (C(0262), CMGYD)
      EQUIVALENCE (C(0265), OMGY)
      EQUIVALENCE (C(0266), CMGZD)
      EQUIVALENCE (C(0269), CMGZ)
      EQUIVALENCE  (C(270) , THTSD)
      EQUIVALENCE  (C(273) , THTS)
      EQUIVALENCE  (C(274) , PSISD)
      EQUIVALENCE  (C(277) , PSIS)
      EQUIVALENCE (C(0279), CMGYS)
      EQUIVALENCE (C(0280) , ANGLT)
      EQUIVALENCE (C(0316), RS)
      EQUIVALENCE (C(0317), FLGT)
      EQUIVALENCE (C(0318), RMT)
      EQUIVALENCE (C(0319), XDT)
      EQUIVALENCE (C(0320), YDT)
      EQUIVALENCE (C(0321), ZDT)
      EQUIVALENCE (C(322), CMZC1D)
      EQUIVALENCE (C(325), CMZC1)
      EQUIVALENCE (C(326), CMYC1D)
      EQUIVALENCE (C(329), CMYC1)
```

```
      EQUIVALENCE (C(335), FLAGS)
      EQUIVALENCE (C(0336), FLGD)
      EQUIVALENCE (C(337), CMGYC)
      EQUIVALENCE (C(338), CMGZC)
      EQUIVALENCE (C(0342), RMA)
      EQUIVALENCE (C(0343), XDA)
      EQUIVALENCE (C(0344), YDA)
      EQUIVALENCE (C(0345), ZDA)
      EQUIVALENCE (C(0346), CMGC)
      EQUIVALENCE (C(0347), FLGTS)
      EQUIVALENCE (C(0348), ERSAZ)
      EQUIVALENCE (C(0349), ERSEL)
      EQUIVALENCE (C(0356), CTHTS)
      EQUIVALENCE (C(0357), STHTS)
      EQUIVALENCE (C(0358), CPSIS)
      EQUIVALENCE (C(0359), SPSIS)
      EQUIVALENCE (C(0416), D1YD)
      EQUIVALENCE (C(0419), D1Y)
      EQUIVALENCE (C(0420), D1ZD)
      EQUIVALENCE (C(0423), D1Z)
      EQUIVALENCE (C(0424), D2YD)
      EQUIVALENCE (C(0427), D2Y)
      EQUIVALENCE (C(0428), D2ZD)
      EQUIVALENCE (C(0431), D2Z)
      EQUIVALENCE  (C(932) , T)
      EQUIVALENCE  (C(946) , TLC)
      DATA AKS/35.0/
      RAD=57.2957795
      IF (T.LT.TLC) GO TO 200
C     GIMBAL ANGLE LIMITS
      GMBLIM=14./RAD
      RXZA=SQRT(XDA**2+ZDA**2)
C
C     TRACKING RATE LIMIT
      TRLIM=20./RAD
      IF (RMA.LE.RS) GO TO 10
      FLAGS=0.0
C     FLAGS SIGNALS START OF SEARCH
C     FLGT SIGNALS SEEKER LOCKON AFTER SEARCH
      FLGT=0.0
C     FLGTS SIGNALS END OF SEARCH
      FLGTS=0.0
C     FLGD SIGNALS DETECTION OF TARGET
      FLGD=0.0
C     FLAGLT SIGNALS TARGET OUTSIDE SEEKER FOV
      FLAGLT=0.0
C     SEEKER POINTING ERRORS-ATIGS TARGET
      ELA=ATAN(-ZDA/XDA)
```

```
      AZA=ATAN(YCA/RXZA)
C     KEEP SEEKER CAGED IF POINTING ERRORS EXCEED GIMBAL LIMITS
      ELA1=ELA
      AZA1=AZA-4./RAD
      IF (ABS(ELA1).GT.GMBLIM) GO TO 200
      IF (ABS(AZA1).GT.GMBLIM) GO TO 200
C     PRECESS SEEKER TO SEARCH INITIATION PT
      CMGYC=AKS*ELA1
      CMGZC=AKS*AZA1
      GO TO 90
C    SEARCH SEQUENCE
   10 IF (FLAGS.GT.0.0) GO TO 20
      TME=T
      FLAGS=1.0
      WRITE (6,150)  RMA,T
   20 IF (FLGTS.GT.0.0) GO TO 75
      TS = T-TME
      IF (TS.GT.0.4) GO TO 30
      CMGYC=-10./RAD
      CMGZC=0.
      CMGC=ABS(CMGYC)
      GO TO 90
   30 IF (TS.GT.1.35) GO TO 40
      CMGYC=0.
      CMGZC=10./RAD
      CMGC=ABS(CMGZC)
      GO TO 90
   40 IF (TS.GT.1.775) GO TO 50
      CMGYC=TRLIM
      CMGZC=0.
      CMGC=ABS(CMGYC)
      GO TO 90
   50 IF (TS.GT.2.4) GO TO 60
      CMGYC=0.
      CMGZC=-TRLIM
      CMGC=ABS(CMGZC)
      GO TO 90
   60 IF (TS.GT.2.625) GO TO 65
      CMGYC=-TRLIM
      CMGZC=0.
      CMGC=ABS(CMGYC)
      GO TO 90
   65 IF (TS.GT.3.425) GO TO 70
      CMGYC=0.
      CMGZC=TRLIM
      CMGC=ABS(CMGZC)
      GO TO 90
C     END OF SEARCH
```

```
   70 IF (FLGC.GT.0.0) GO TC 90
      CMGZC=C.C
      CMGYC=C.C
      WRITE (6,130)
      FLGTS=1.C
      GO TC SC
   75 IF (FLGC.GT.0.0) GC TC 80
      GO TC SC
C  8C REPCSITICN SEEKER ON DETECTED TARGET
   8C IF (FLGT.GT.0.0) GC TC 85
      RYZT=SQRT(YDT**2+ZDT**2)
      CMGYC=-TRLIM*ZDT/RYZT
      CMGZC=TRLIM*YDT/RYZT
      IF (ANGLT.LE.0.25) FLGT=1.0
      GO TC SC
C    RADIOMETER AND SENSCR FILTER LAGS
   85 WS=201.
      WSF=125.7
      D1YD=WS*(.2*ERSEL-D1Y)
      C1ZD=WS*(.2*ERSAZ-C1Z)
C     RECEIVER NCISE MCDEL
      SGMNOI=3.C4815E-05*RMT*2.718282**(RMT*5.614624E-06)
      ELNCIS=0.2*SGMNOI*CNCIS1
      AZNOIS=C.2*SGMNOI*CNCIS2
C     ADD NOISE TO FILTERED RADIOMETER SIGNAL
      D1YN=C1Y+ELNCIS
      C1ZN=C1Z+AZNOIS
      CMYC1C=WSF*(AKS*D1YN/RAD-OMYC1)
      OMZC1C=WSF*(AKS*D1ZN/RAD-OMZC1)
      CMGZC=OMZC1
      CMGYC=CMYC1
C     IF SEEKER LCSES TGT,PRECESSICN COMMANDS GO TC ZERO
      IF (ABS(ANGLT).LE.2.5) GC TO 90
   88 IF(FLAGLT.GT.0.0)  GC TC 90
      WRITE (6,140) ANGLT
      FLAGLT=1.0
C     SEEKER PRECESSION RATES
   9C IF (ABS(CMGYC).GE.TRLIM)  OMGYC=SIGN(TRLIM,CMGYC)
      IF (ABS(CMGZC).GE.TRLIM)  OMGZC=SIGN(TRLIM,OMGZC)
C    RESOLVE GIMBAL Y-AXIS ANG RATE TO SEEKER Y-AXIS
      OMGYS=CMGY*CPSIS+SPSIS*(R*STHTS-P*CTHTS)
C    SEEKER CYNAMICS
      D2YD=2.4*(CMGYC-OMGYS)
      CMGYD=2139.*(D2Y+D2YC/64.3)
      D2ZD=4.4*(CMGZC-OMGZ)
      CMGZD=1445.925*(D2Z+D2ZD/64.3)
C     SEEKER EULER ANGLE RATES
      THTSD=CMGY-Q
```

```
      PSISD=CMGZ-P*STHTS-R*CTHTS
      THTLIM=SIGN(GMBLIM,THTS)
      PSILIM=SIGN(GMBLIM,PSIS)
      IF(ABS(THTS).GT.GMBLIM)  THTSD=50.*(THTLIM-THTS)
      IF(ABS(PSIS).GT.GMBLIM)  PSISD=50.*(PSILIM-PSIS)
  200 RETURN
 130  FORMAT(1H,10X,'END OF SEARCH,NO TARGET DETECTION')
  140 FORMAT  (1H,10X,'SEEKER LOST TARGET,LOOK ANGLE=',F8.3)
  150 FORMAT  (1H,10X,'START SEARCH,ATIGS TGT RGE=',F10.3,3X,'T=',F8.3)
      END
C
C
C
      SUBROUTINE S2I
C
      COMMON C(3415)
      EQUIVALENCE (C(0336), FLGD)
      EQUIVALENCE (C(0347),FLGTS)
      FLGD=0.0
      FLGTS=0.0
      RETURN
      END
C
C
      SUBROUTINE S2
C
C     RADIOMETER MODULE  S2
C
      COMMON C(3415)
      EQUIVALENCE (C(0172), BTA02)
      EQUIVALENCE (C(0224), A11)
      EQUIVALENCE (C(0228), A12)
      EQUIVALENCE (C(0232), A13)
      EQUIVALENCE (C(0236), A21)
      EQUIVALENCE (C(0240), A22)
      EQUIVALENCE (C(0244), A23)
      EQUIVALENCE (C(0248), A31)
      EQUIVALENCE (C(0252), A32)
      EQUIVALENCE (C(0256), A33)
      EQUIVALENCE (C(0273), THTS)
      EQUIVALENCE (C(0277), PSIS)
      EQUIVALENCE (C(0280), ANGLT)
      EQUIVALENCE (C(0290), XTP)
      EQUIVALENCE (C(0298), YTP)
      EQUIVALENCE (C(0306), ZTP)
      EQUIVALENCE (C(0310), XTTP)
      EQUIVALENCE (C(0311), YTTP)
      EQUIVALENCE (C(0312), ZTTP)
```

```
      EQUIVALENCE (C(0313), XATP)
      EQUIVALENCE (C(0314), YATP)
      EQUIVALENCE (C(0315), ZATP)
      EQUIVALENCE (C(0316), RS)
      EQUIVALENCE (C(0317), FLGT)
      EQUIVALENCE (C(0318), RMT)
      EQUIVALENCE (C(0319), XDT)
      EQUIVALENCE (C(0320), YDT)
      EQUIVALENCE (C(0321), ZDT)
      EQUIVALENCE (C(335), FLAGS)
      EQUIVALENCE (C(0336), FLGD)
      EQUIVALENCE (C(0339), X2)
      EQUIVALENCE (C(0340), Y2)
      EQUIVALENCE (C(0341), Z2)
      EQUIVALENCE (C(0342), RMA)
      EQUIVALENCE (C(0343), XDA)
      EQUIVALENCE (C(0344), YDA)
      EQUIVALENCE (C(0345), ZDA)
      EQUIVALENCE (C(0346), OMGC)
      EQUIVALENCE (C(0347), FLGTS)
      EQUIVALENCE (C(0348), ERSAZ)
      EQUIVALENCE (C(0349), ERSEL)
      EQUIVALENCE (C(0356), CTHTS)
      EQUIVALENCE (C(0357), STHTS)
      EQUIVALENCE (C(0358), CPSIS)
      EQUIVALENCE (C(0359), SPSIS)
      EQUIVALENCE (C(0932), T)
      EQUIVALENCE (C(0946), TUC)
      RAD=57.2957795
      X1=XTTP-XTP
      Y1=YTTP-YTP
      Z1=ZTTP-ZTP
      X2=XATP-XTP
      Y2=YATP-YTP
      Z2=ZATP-ZTP
C     TARGET POSITION IN BODY AXIS SYSTEM
      XMT=A11*X1+A12*Y1+A13*Z1
      YMT=A21*X1+A22*Y1+A23*Z1
      ZMT=A31*X1+A32*Y1+A33*Z1
      RMT=SQRT(XMT**2+YMT**2+ZMT**2)
C     ATIGS TGT POSITION IN BODY AXIS SYSTEM
      XMA=A11*X2+A12*Y2+A13*Z2
      YMA=A21*X2+A22*Y2+A23*Z2
      ZMA=A31*X2+A32*Y2+A33*Z2
      RMA=SQRT(XMA**2+YMA**2+ZMA**2)
      IF (T.LT.TUC) GO TO 200
C     SEEKER DIRECTION COSINES WRT BODY (PITCH-YAW SEQUENCE)
      CTHTS=COS(THTS)
```

```
      STHTS=SIN(THTS)
      CPSIS=COS(PSIS)
      SPSIS=SIN(PSIS)
      B11=CPSIS*CTHTS
      B12=SPSIS
      B13=-CPSIS*STHTS
      B21=-SPSIS*CTHTS
      B22=CPSIS
      B23=SPSIS*STHTS
      B31=STHTS
      B32=0.
      B33=CTHTS
C    RESOLVE TGT POSITION FROM BODY SYSTEM TO SEEKER AXES
      XDT=B11*XMT+B12*YMT+B13*ZMT
      YDT=B21*XMT+B22*YMT+B23*ZMT
      ZDT=B31*XMT+B32*YMT+B33*ZMT
      RYZT=SQRT(YDT**2+ZDT**2)
      RXYT=SQRT(XDT**2+YDT**2)
C    RESOLVE ATIGS TGT POSITION FROM BODY SYSTEM TC SEEKER AXES
      XDA=B11*XMA+B12*YMA+B13*ZMA
      YDA=B21*XMA+B22*YMA+B23*ZMA
      ZDA=B31*XMA+B32*YMA+B33*ZMA
      IF (FLAGS.GT.0.0) GO TO 5
      FLG1=0.0
      GO TO 200
    5 ANGLTR=ATAN(RYZT/XDT)
      ANGLT=ANGLTR*RAD
      IF (FLGTS.GT.0.0) GO TO 30
C     BETA=EFFECTIVE SEARCH BEAM WIDTH (DEG)
      BETA=6.2-7.07E-09*SQRT(CMGC*RAD/20.)*RMA**2
      BTAC2=BETA/2.0
C    TEST FOR TARGET DETECTION
      IF (FLG1.GT.0.0) GO TO 10
C    FLG1 SET WHEN TARGET ENTERS BEAM
      IF (ABS(ANGLT).LE.BTAC2) FLG1=1.0
      GO TO 200
   10 IF (FLGD.GE.1.0) GO TO 20
      TME=T
C    FLGD SET WHEN TARGET LEAVES BEAM
      IF (ABS(ANGLT).GE.BTAC2) FLGD=1.0
      GO TO 200
   20 TD=T-TME
C    DETECTION DECLARED 30 MSEC AFTER TGT LEAVES BEAM
      IF (TD.GE.0.03) GO TO 25
      GO TO 200
   25 IF (FLGTS.GE.1.0) GO TO 30
      WRITE (6,160) T
      FLGTS=1.0
```

```
      GO TC 200
   30 IF (FLGT.LE.0.0) GC TC 200
C     RADICMETER ERROR SIGNAL
      CHI1=2.0193*(2.*ANGLT/3.-1.0)
      CHI2=2.C193*(2.*ANGLT/3.+1.0)
      IF (CHI1.EC.0.0) GO TC 4C
      ERSIG=(SIN(CHI1)/CHI1)**2-(SIN(CHI2)/CHI2)**2
      GO TC 50
   40 ERSIG=1.C-(SIN(CHI2)/CHI2)**2
C     ERSIG=ZERC IF SEEKER LCSES TRACK
   50 IF (ANGLT.GT.2.5)  ERSIG=0.0
C     RESCLVE INTC AZ,EL ERRCR SIGNALS (SMALL ANGLE APPROX)
      IF (RYZT.LE.0.0) GC TC 6C
      ERSAZ=ERSIG*YDT/RYZT
      ERSEL=ERSIG*(-ZDT)/RYZT
      GO TC 2CC
   6C ERSAZ=C.C
      ERSEL=C.0
  2CC RETURN
 160  FORMAT (1H,10X,'END CF SEARCH,TARGET DETECTED.T=',F8.3)
      END
C
C
C
      SUBRCUTINE S3I
      RETURN
      END
C
C
      SUBRCLTINE S3
      RETURN
      END
C
C
      SUBROLTINE S4I
      RETURN
      END
C
C
      SUBRCLTINE S4
      RETURN
      ENC
C
C
      SUBPOUTINE S5I
      RETURN
      END
C
```

```
C
C
      SUBROUTINE S5
C
C   ACCELEROMETERS AND GYROS MODULE
C
      COMMON C(3415)
      EQUIVALENCE (C(0136),CG)
      EQUIVALENCE (C(0212),P)
      EQUIVALENCE (C(0213),QD)
      EQUIVALENCE (C(0216),Q)
      EQUIVALENCE (C(0217),RD)
      EQUIVALENCE (C(0220),R)
      EQUIVALENCE (C(710), AX)
      EQUIVALENCE (C(0711),AY)
      EQUIVALENCE (C(0712),AZ)
      EQUIVALENCE (C(1644),AZM)
      EQUIVALENCE (C(1648),AYM)
      EQUIVALENCE (C(1652),QM)
      EQUIVALENCE (C(1656),RM)
      EQUIVALENCE (C(0980), FM)
      EQUIVALENCE (C(1749),XAD)
      DATA FLGA/0.0/
C   ACCELEROMETER OFFSET FROM CG
C     ACCELEROMETERS AT STA. 134.5
      XACC=CG-4.9433
      AX1=AX-XACC*(R**2+Q**2)
      AZ1=AZ+XACC*(R*P-QD)
      AY1=AY+XACC*(Q*P+RD)
      IF (FLGA.GT.0.0) GO TO 10
C     IDEAL ACCELEROMETERS
      AXM=AX1
      AYM=AY1
      AZM=AZ1
      GO TO 20
C     DIGITAL ACCELEROMETERS
C       TRANSFORMATION TO SKEWED ACCELEROMETER AXES
   10 BA11=.57735027
      BA12=BA11
      BA13=BA11
      BA21=-.70710678
      BA22=-BA21
      BA23=0.
      BA31=BA11*BA21
      BA32=BA31
      BA33=-2.0*BA31
      AXA=BA11*AX1+BA12*AY1+BA13*AZ1
      AYA=BA21*AX1+BA22*AY1+BA23*AZ1
```

```
      AZA=BA31*AX1+BA32*AY1+BA33*AZ1
C     ACCELEROMETER QUANT. STEP=.194 G
      AQS=6.24176
      ANSX=AXA/AQS
      AXMA=AQS*AINT(ANSX)
      ANSY=AYA/AQS
      AYMA=AQS*AINT(ANSY)
      ANSZ=AZA/AQS
      AZMA=AQS*AINT(ANSZ)
C      TRANSFORMATION BACK TO BODY AXES
      AXM=BA11*AXMA+BA21*AYMA+BA31*AZMA
      AYM=BA12*AXMA+BA22*AYMA+BA32*AZMA
      AZM=BA13*AXMA+BA23*AYMA+BA33*AZMA
C  ***** IDEAL GYROS *****
   20 QM=Q
      RM=R
      PM=P
      RETURN
      END
C
C
      SUBROUTINE S6I
      RETURN
      END
C
C
      SUBROUTINE S6
      RETURN
      END
C
C
      SUBROUTINE S7I
      RETURN
      END
C
C
      SUBROUTINE S7
      RETURN
      END
C
C
      SUBROUTINE S8I
      RETURN
      END
C
C
      SUBROUTINE S8
      RETURN
```

```
      END
C
C
      SUBROUTINE S9I
      RETURN
      END
C
C
      SUBROUTINE S9
      RETURN
      END
C
C
      SUBROUTINE S10I
      RETURN
      END
C
C
      SUBROUTINE S10
      RETURN
      END
C
C
C
      SUBROUTINE BOOST (TT,THRUST,FF)
C
      DIMENSION T(25),F(25),W(25)
      COMMON C(3415)
      EQUIVALENCE (C(0933),T1)
      EQUIVALENCE (C(0507), F)
C
      DATA T(1)/0.0/,T(2)/.075/,T(3)/.08/,T(4)/.10/,T(5)/.50/,T(6)/1.0/,
     1T(7)/1.50/,T(8)/1.75/,T(9)/1.95/,T(10)/2.125/,T(11)/3.125/,
     2T(12)/3.505/,T(13)/3.70/,T(14)/3.80/,T(15)/3.875/,T(16)/3.95/,
     3T(17)/4.025/,T(18)/4.075/,T(19)/4.15/,T(20)/4.20/,T(21)/4.25/,
     4T(22)/4.35/,T(23)/4.475/,T(24)/4.60/,T(25)/4.75/
C
      DATA F(1)/0.0/,F(2)/2000./,F(3)/16000./,F(4)/17800./,F(5)/19200./,
     1F(6)/21500./,F(7)/24100./,F(8)/25100./,F(9)/25800./,F(10)/26100./,
     2F(11)/26500./,F(12)/26500./,F(13)/26400./,F(14)/25600./,
     3F(15)/24800./,F(16)/24000./,F(17)/22000./,F(18)/16000./,
     4F(19)/12000./,F(20)/9000./,F(21)/6900./,F(22)/4000./,F(23)/1900./,
     5F(24)/900./,F(25)/0.0/
C
      DATA W(1)/0.0/,W(2)/.321/,W(3)/2.841/,W(4)/6.575/,W(5)/61.178/,
     1W(6)/111.759/,W(7)/148.870/,W(8)/172.301/,W(9)/182.143/,
     2W(10)/206.751/,W(11)/255.867/,W(12)/362.863/,W(13)/376.037/,
     3W(14)/381.912/,W(15)/388.351/,W(16)/392.396/,W(17)/397.734/,
```

```
     4W(18)/401.847/,W(19)/404.344/,W(20)/406.206/,W(21)/407.368/,
     5W(22)/408.396/,W(23)/409.175/,W(24)/409.883/,W(25)/410.296/
C
      TIME=TT-T1
      IF(TIME.GT.0.) GO TO 3
      FF = 0.0
      THRUST = 0.0
      GO TO 4
 3    DO 1 I = 2,25
      IF(T(I).GE.TIME) GO TO 2
 1    CONTINUE
      CALL EXIT
    2 AK=(TIME-T(I-1))/(T(I)-T(I-1))
      THRUST = F(I-1) + (F(I) - F(I-1))*AK
      FF = W(I-1) + (W(I) - W(I-1))*AK
       PSF=2116.217*((1.0-(6.875347035E-06)*H)**5.25627005)
      THRUST=THRUST+(2116.2-PSF)*.715428
 4    RETURN
      END
C
C
C
      SUBROUTINE RAMJET (HIN,XMIN,AIN,WFIN,XIN,CT)
C
C  SIMPLIFIED RAMJET MODEL
C   USES TABLE LOOK-UP FOR THRUST COEFF AND FUEL FLOW RATE
C
      DIMENSION TM1(6),TM2(7),TH(4),TETA(5),TCF1(6,5,4),TCF2(7,5,4),
     1TWF(6,5,4)
      COMMON C(3415)
C
      DATA TM1/2.3,2.5,2.7,2.9,3.1,3.3/
C
      DATA TM2/0.5,1.0,1.5,2.0,2.5,3.0,3.3/
C
      DATA TH/500.,13000.,20000.,35000./
C
      DATA TETA/0.,2.,4.,6.,8./
C
      DATA TCF1/ .3814,.2958,.2075,.1374,
     A.0844,.0443, .3794,.2843,.2025,.1339,.0805,.0402, .3731,.2818,
     B.1915,.1203,.0666,.0258, .3476,.2526,.1699,.1049,.0555,.0173,
     C .3251,.2355,.1595,.1001,.0549,.0201,  .4357,.3412,.2453,.1691,
     D.1115,.0682, .4337,.3293,.2401,.1654,.1075,.0639, .4273,.3268,
     E.2287,.1512,.0927,.0485, .4012,.2967,.2061,.1350,.0810,.0396,
     F .3782,.2791,.1954,.1300,.0805,.0425,  .4944,.386,.2798,.1963,
     G.1341,.088, .4924,.373,.2742,.1924,.1296,.0832, .4857,.3706,.2618,
     H.1766,.1132,.066, .4573,.3376,.237,.1588,.1003,.056, .4328,.3186,
```

```
     I.2254,.1535,.0999,.0595,  .6273,.5139,.3961,.2997,.2243,.1661,
     J .625,.5028,.3911,.296,.2202,.1616, .6179,.4998,.3801,.2821,.2054,
     K.1459, .5931,.4721,.3588,.2662,.1936,.1367, .5708,.4555,.3484,
     L.2613,.1932,.1398/
C
      DATA TCF2/-.5727,-.3661,-.4238,
     A-.2615,-.2067,-.2074,-.2091, -.5727,-.3658,-.4235,-.2618,-.2067,
     B-.2072,-.209, -.5728,-.3655,-.4233,-.2623,-.2065,-.2069,-.2089,
     C -.5729,-.3631,-.4218,-.2635,-.2064,-.2065,-.2086, -.5731,-.3618,
     D-.4205,-.2648,-.2062,-.2061,-.2081,  -.5692,-.3649,-.4226,-.2603,
     E-.2055,-.2060,-.2075, -.5693,-.3646,-.4223,-.2606,-.2054,-.2058,
     F-.2074, -.5693,-.3643,-.4221,-.2612,-.2053,-.2055,-.2073, -.5695,
     G-.3619,-.4207,-.2624,-.2052,-.2051,-.207, -.5697,-.3606,-.4194,
     H-.2636,-.205,-.2047,-.2065,  -.5659,-.3637,-.4212,-.259,-.204,
     I-.2041,-.2054, -.5659,-.3633,-.421,-.2593,-.2039,-.2039,-.2052,
     J -.566,-.3631,-.4208,-.2598,-.2038,-.2036,-.2052, -.5662,-.3606,
     K-.4194,-.261,-.2037,-.2032,-.2048, -.5664,-.3594,-.4181,-.2622,
     L-.2035,-.2028,-.2044,  -.5553,-.3602,-.4186,-.2569,-.2027,-.203,
     M-.2043, -.5554,-.3599,-.4184,-.2572,-.2026,-.2028,-.2042, -.5555,
     N-.3596,-.4182,-.2577,-.2025,-.2025,-.2042, -.5557,-.3572,-.4168,
     O-.2589,-.2023,-.2021,-.2038, -.5559,-.356,-.4156,-.2601,-.2021,
     P-.2017,-.2033/
C
      DATA TWF/ 2.95,2.95,2.885,2.835,
     A2.806,2.806, 2.941,2.882,2.853,2.805,2.771,2.763, 2.911,2.867,
     B2.779,2.703,2.65,2.619, 2.778,2.7,2.64,2.588,2.552,2.532, 2.665,
     C2.604,2.571,2.549,2.542,2.553,  1.966,1.966,1.927,1.894,1.877,
     D1.876, 1.961,1.924,1.906,1.876,1.855,1.849, 1.942,1.914,1.86,
     E1.812,1.779,1.76, 1.859,1.81,1.773,1.74,1.718,1.706, 1.788,1.751,
     F1.73,1.716,1.712,1.718,  1.561,1.561,1.532,1.507,1.494,1.493,
     G 1.557,1.529,1.516,1.493,1.477,1.473, 1.543,1.522,1.481,1.445,
     H1.42,1.406, 1.48,1.444,1.416,1.391,1.375,1.365, 1.427,1.399,1.383,
     I1.373,1.37,1.375,  .968,.968,.952,.94,.933,.933, .965,.951,.944,
     J.933,.924,.922, .958,.947,.926,.908,.895,.888, .926,.907,.893,.88,
     K.872,.867, .899,.884,.876,.871,.869,.872/
C
      H=HIN*3.280839895
      IF (XIN.GT.0.0) GO TO 10
C     RAMJET-ON CRUISE
      CT=THRECL(XMIN,AIN,H,TM1,TETA,TH,TCF1,6,5,4)
      WFIN=THRECL(XMIN,AIN,H,TM1,TETA,TH,TWF,6,5,4)
      GO TO 20
C     RAMJET-OFF CRUISE
   10 CT=THRECL(XMIN,AIN,H,TM2,TETA,TH,TCF2,7,5,4)
      WFIN=0.0
   20 RETURN
      END
C
```

```
C
C
      SUBROUTINE ENGINE (HIN,XMIN,AIN,WFIN,TIN,XIN,YIN,ZIN,CT,SMARG,
     1                   IFI,IREAD)
C
C
C
C     NWC COMMON DECK FOR AIRBREATHING PROPULSION PROGRAMS
C     CPIA NOMENCLATURE
C
      REAL ISP,ISTAR,M,M1,M2,M3,M4,M5,M6,MW,MW1,MW2,MW3,MW4,MW5,MW6
      REAL MACR,MACRS,MACH
      INTEGER COUNT
C
      COMMON/CRLS/  ENG(30),IENG(15)
      COMMON /RJ/ A,AINF,A1,A2,A3,A4,A5,A6,AR,AFR,AFS,ALPHA
      COMMON /RJ/ ACR,BLEED
      COMMON /RJ/ CDASUB,CDASUP,CDB,CF,CFINF,CF6,CFB,CFT,CFC,CNM
      COMMON /RJ/ ER,ERRL,ERLL,ETAC,ETAN,F
      COMMON /RJ/ FAR,G,GAMMA,GAMMA1,GAMMA2,GAMMA3,GAMMA4,GAMMA5,GAMMA6
      COMMON /RJ/ H,ISP,ISTAR,I1,I2,I3,I4,I5,I6,I7,I8,I9,I10
      COMMON /RJ/ COUNT,ICONV,ICONVP,IFIRST
      COMMON /RJ/ M,M1,M2,M3,M4,M5,M6,MW,MW1,MW2,MW3,MW4,MW5,MW6
      COMMON /RJ/ MACR,MACRS,PM
      COMMON /RJ/ P,P1,P2,P3,P4,P5,P6,PT30I,PRAR
      COMMON /RJ/ PT,PT1,PT2,PT3,PT4,PT5,PT6,PMOPT,PMOPT1,PMOPT2,PMOPT3
      COMMON /RJ/ PHI1,PHI2,PHI3,PHI4,PHI5,PHI6,PHIPRI,Q
      COMMON /RJ/ RADEG,R,SA,SART,SQPTOT
      COMMON /RJ/ T,T1,T2,T3,T4,T5,T6,TIME
      COMMON /RJ/ TT,TT1,TT2,TT3,TT4,TT5,TT6
      COMMON /RJ/ V,V1,V2,V3,V4,V5,V6
      COMMON /RJ/ WA,WF,X,Y,Z
C
C     *     *     *     *     *     *     *
C
      COMMON /EXHALS/ TABLE(1000)
C
      COMMON /WRITCT/ WRIT(20)
C
      NAMELIST /MCNT/ ENG,IENG
C
C      *** THE INFORMATION BELOW NOTES HOW THE NAMELIST
C      DATA IS INPUT AND WHAT THE INPUTS ARE ***
C
C     ENG(1)=A1/AR OR A1 (M SQ)  SEE I6
C     ENG(2)=A3/AR OR A3 (M SQ)  SEE I6
C     ENG(3)=A4/AR OR A4 (M SQ)  SEE I6
C     ENG(4)=A5/AR OR A5 (M SQ)  SEE I6
```

```
C       ENG(5)=A6/AR OR A6 (M SQ)  SEE I6
C       ENG(6)=AR (METRES SQUARED)
C       ENG(7)=CDE  BURNER DRAG COEFFICIENT
C       ENG(8)=ETAN, NOZZLE THRUST EFFICIENCY
C       ENG(9)=ETAC, COMBUSTION EFFICIENCY
C       ENG(10)=WF,  FUEL FLOW RATE (KG/SEC) SEE I5
C       ENG(11)=ISP STAR (FOR GAS GENERATOR SYSTEMS)
C       ENG(12)=PHI OF PRIMARY (FOR GAS GEN SYSTEMS)
C       ENG(13)=BLEED FLOW PERCENTAGE/ 100.
C       ENG(14)=AIR TO FUEL STOICHEMETRIC (AFS)
C       ENG(15)=CNM, NOZZLE MASS FLOW COEFFICIENT
C
        REAL MCOSE
        DIMENSION  MCOSE(176), EAGLE(176)
C
C  *** THE INPUTS BELOW ARE SWITCHES ***
C       IENG(1)=I1, ENGINE TYPE SWITCH
C          IF I1=0,RAMJET TYPE  IF I1=1, GAS GEN TYPE
C       IENG(2)=I2, COMBUSTION EFF SWITCH
C          IF I2=0,ETAC IS SET BY INPUT
C          IF I2=1,ETAC IS SET IN A SUBROUTINE
C       IENG(3)=I3, ATMOSPHERE CHOICE SELECTION, SEE MEMO BY RGL
C           I3=2 IS STANDARD DAY
C       IENG(4)=I4, REAL AIR SWITCH
C          IF I4=0, USE THE REAL AIR SOLUTION
C          IF I4=1, USE THE GAMMA=1.4 SOLUTION
C       IENG(5)=I5, WF OR ER SOLUTION SWITCH
C          IF I5=1, THE PROGRAM USES ER IN THE SOLUTION
C          IF I5=2, THE PROGRAM USES WF IN THE SOLUTION
C        IENG(6)=I6, INLET DATA TYPE SWITCH
C           IF I6=0, THE INPUTS ARE RATIOS BASED ON AR
C           IF I6=1, THE AREAS ARE ABSOLUTE VALUES
C          IENG(7)=I7, PRINT EACH ITERATION SWITCH
C            IF I7=0, DO NOT PRINT DEBUG DATA EACH ITERATION
C           IF I7.NE.0, DO PRINT DEBUG DATA
C           IENG(8)=I8, COMBUSTION PRESSURE EFFECT SWITCH
C             IF I8=0,THERE IS NO PRESSURE EFFECT COMPUTED
C             IF I8=1, THE PRESSURE EFFECT ON COMBUSTION TEMP IS COMPUTED
C
        EQUIVALENCE(TABLE(206),MCOSE(1))
        EQUIVALENCE(TABLE(382),EAGLE(1))
C
C  *** EXAMPLE OF NAMELIST INPUT ***
C     $MCNT
C     ENG=.5256,.85,.85,.44444,.96,.1140092,0.,.98,.95,2.,.50,1.2,.04,13.8
C     1.0,
C     IENG=0,0,2,0,1,0,0,0,
C     $END
```

```
C
      IF (IREAD.EQ.1) GO TO 10
C     CMMENT  READ IN DATA AND RETURN TO CALLING ROUTINE
      READ (5,MCNT)
      WRITE (6,MCNT)
      RETURN
C     CMMENT  PUT DATA IN FORM THAT THE ATHODYD PROGRAM CAN USE
   10 CONTINUE
      MACH=0.0
      H=HIN
      M=XMIN
      ALPHA=AIN
      WF=WFIN
      TIME=TIN
      IF(WFIN.LT.0.0001.AND.TIME.GT.20.) IFUEL=4
      IFIRST=IFI
C                             X=XIN            @  GAMMA
      X=XIN
C                             Y=YIN            @  NOT USED
      Y=YIN
C                             Z=ZIN            @  NOT USED
      Z=ZIN
      A1=ENG(1)
      IF(TIME.LT.10.0) A1=.43244
      IF(TIME.GT.10.0.AND.TIME.LT.50.0) A1=.43162+.00008639*TIME
      IF (TIME.GE.50.0) A1=.43594
      A3=ENG(2)
      A4=ENG(3)
      IFUEL=0
      IF(XIN.GE.1.0) IFUEL=5
      IF(TIME.LE.12.5) A5=.50326
      IF(TIME.GT.12.5.AND.TIME.LE.40.) A5=.51410+.00023839*TIME
      IF(TIME.GT.40..AND.TIME.LE.66.) A5=.51776+.00014694*TIME
      IF(TIME.GT.66.) A5=.52746
      A6=ENG(5)
      AR=ENG(6)
      CDB=ENG(7)
      ETAN=ENG(8)
      ETAC=ENG(9)
      IF (IENG(5).EQ.2) WF=ENG(10)
      ISTAR=ENG(11)
      PHIPRI=ENG(12)
      BLEED=ENG(13)
      AFS=ENG(14)
      CNM=ENG(15)
      IF (CNM.LT.0.5) CNM=1.0
      I1=IENG(1)
      I2=IENG(2)
```

```
      I3=IENG(3)
      I4=IENG(4)
      I5=IENG(5)
      I6=IENG(6)
      I7=IENG(7)
      I8=IENG(8)
      IF (I6.EQ.0) A1=A1*AR
      IF (I6.EQ.0) A3=A3*AR
      IF (I6.EQ.0) A4=A4*AR
      IF (I6.EQ.0) A5X=A5*AR
      IF (I6.EQ.0) A6=A6*AR
      IF (I6.EQ.1) A5X=A5
      A5=A5X*CNM
      IF (IFIRST.EQ.-1) GO TO 20
      GO TO 30
   20 CONTINUE
C     CMMENT  INITIALIZE ,SET CONSTANTS AND WRITE AREAS
C
C
C      AIRBREATHING GEOMETRY       ONLY CALLED ON FIRST PASS
C     CALCULATE GEOMETRY PARAMETERS
C
C
      A40A5=A4/A5
      GAM=9.0/7.0
      M4=FMARL(GAM,A40A5)
      PHI4=PHIM(GAM,M4)
      A60A5=A6/A5
      M6=FMARH(GAM,A60A5)
      PHI6=PHIM(GAM,M6)
C
C     IDENTIFY AND PRINT PARAMETERS
C
      WRITE (6,420)
      WRITE (6,430) A1
      WRITE (6,440) A3
      WRITE (6,450) A4
      WRITE (6,460) A5X
      WRITE (6,470) A6
      WRITE (6,480) AR
      WRITE (6,490) PHI4
      WRITE (6,500) PHI6
      WRITE (6,510) CDB
      WRITE (6,520) CNM
   30 CONTINUE
C
C     SET CONSTANTS AND INITIALIZE SUBROUTINES
C                           G IN KG M/SEC SQ - N
```

```
C
      RADEG=.572957779E+02
      G=9.80665
C
C     START CALCULATIONS FOR EACH NEW POINT
C
      COUNT=0
      ICONVP=1
C
C     NEW ITERATIONS START HERE
C
   40 ICONV=0
C
C     CHECK TO SEE IF 100 ITERATIONS OF THE SAME POINT HAVE BEEN MADE
C
      IF (COUNT-100) 60,60,50
C
C     IF NOT CONVERGED AFTER 100 ATTEMPTS, STOP
C
   50 WRITE (6,530)
C
      CALL EXIT
C     IF NOT CONVERGED WITH LESS THAN 100 ATTEMPTS, TRY AGAIN
C
   60 CONTINUE
      IF(COUNT.GT.89) I7=10
C     IF ABOVE STATEMENT NOT CONVERG,PRINT LAST 10
      IF (COUNT.NE.0) GO TO 90
      IF (IFIRST.EQ.-1) CALL AIR(H,M,-1,P,T,A,DEN,Q,G,1,1)
      IF (IFIRST.EQ.-1) GO TO 70
      I3=I3+100
      CALL AIR(H,M,1,P,T,A,DEN,Q,G,1,1)
   70 G=9.80665
      IF (I4.EQ.1) GO TO 80
C                             ENTHR IN CAL/GM
      ENTHR=46.4278+.23945*(T-194.444)
C                             V IN METRES PER SEC
      V=M*A
C                             ENERG IN CAL/GM
      ENERG=(V**2.)/8368.
      ENTHAL=ENTHR+ENERG
C                             ECGM IN CAL/GM
      ECGM=ENTHAL+ENERG
C                             TT3 IN DEGREE RANKINE
      TT3=539.31+(7.5164*ECGM)-(3.3559E-03*ECGM*ECGM)+(4.65976E-06*(ECGM
     1**3.))-(5.32956E-09*(ECGM**4.))
      TT3=TT3/1.8
      GAMMA3=1.4048-(6.09654E-04*ECGM)+(2.12102E-06*ECGM*ECGM)-(5.56849E
```

```
     1-09*(ECGM**3.))+(6.49543E-12*(ECGM**4.))
      GO TO 90
   80 CONTINUE
      GAMMA3=1.4
      TT3=T/FTOTT(1.4,M)
      T3=TT3*FTOTT(1.4,M3)
   90 CONTINUE
C
      IF (IFIRST) 100,110,110
  100 WRITE (6,540)
C
C     COMBUSTOR
C
      IF (I2.EQ.1) CALL ETA
      CALL TAB (AFS)
      V=-0.0
      WA=10.0
      M3=.2
      MACRS=1.
      CALL HORA
C
C     CALCULATION
C
      WRITE (6,230)
C
C     DIFFUSER
C
      CALL HOF
      GO TO 190
  110 CONTINUE
      IF (M.GT.1.07) GO TO 130
C       ***** BEGIN SUBSONIC CALL SEQUENCE *****
      IF (WF.LT..001) GO TO 120
      PT=P/FPOPT(1.4,M)
      PMOPT=FPMOPT(1.4,M)
      TT=T/FTOTT(1.4,M)
      ACR=.27661+2.4721*M-4.527*M*M+2.3036*M*M*M
      AINF=A1*ACR*1.05
      WA=(AINF*PT*PMOPT)/SQRT(TT)
      CALL HORA
  120 CONTINUE
      IF (WF.LT..001) ER=0.0
      FAR=ER/AFS
      CALL SUBSON (H,M,FAR,CF,WF,Q,AR)
      ICONV=0
      COUNT=0
      GO TO 225
C       *****  END OF SUBSONIC CALL SEQUENCE ****
```

```
  130 CONTINUE
C
C        ********  WE SET SA HERE ********
C
      IF (I5.EQ.1) GO TO 140
      IF (I5.EQ.2) GO TO 150
      WRITE (6,240)
C GO THIS ROUTE IF ER IS INPUT OR CHANGED IN HCRA
  140 CONTINUE
      CALL HCRA
      IF(IFUEL.EQ.5) ER=0.0
      FAR=ER/AFS
      WF=FAR*WA
      AFR=1./FAR
      GO TO 160
C GO THIS ROUTE IS WF IS INPUT OR SET IN HCRA
  150 CONTINUE
      CALL HCRA
      IF(IFUEL.EQ.5) WF=0.0
      FAR=WF/WA
      ER=FAR*AFS
      IF(FAR.EQ.0.0) GO TO 1400
      AFR=1.0/FAR
      GO TO 160
 1400 AFR=0.0
C
  160 CONTINUE
C
      TOTT3=FTOTT(GAMMA3,M3)
      T3=TT3*TOTT3
      SQRTOT=SQRT(TT3)
C
C     TO FIND AIR SPECIFIC IMPULSE
C
      IF(I10.EQ.0) GO TO 161
      CONTINUE
      GO TO 169
  161 CONTINUE
      CALL INTR20 (TT3,ER,TT4I,TABLE,1)
      CALL INTR20 (TT3,ER,GAMMA4,TABLE,2)
      CALL INTR20 (TT3,ER,MW4,TABLE,3)
C
C      COMPUTE THE EFFECT OF PRESSURE ON TEMPERATURE
C
       IF(I8.EQ.0) GO TO 162
      G1=GAMMA4+1.0
      G2=GAMMA4-1.0
      G3=G1/G2
```

```
      G4=2.*G1*((2./G1)**G3)
      G5=SQRT(G4)
      PT4=(SA*WA)/(G5*A5)
      PT4ATM=PT4/101360.
      IF(PT4ATM.LT. .2) PT4ATM=.2
      IF(PT4ATM.GT. 20.) PT4ATM=20.
      IF(TT3.LT.299.) GO TO 1615
      IF(ER.GT.1.5) GO TO 1615
      CTEMP=TC(TT3,ER,PT4ATM)
 1615 CONTINUE
      TT4I=TT4I+CTEMP
  162 CONTINUE
C
C  NOW FINISH COMBUSTOR COMPUTATIONS
C
      R=8314.34/MW4
      WAX=WA/.4535924
      THROAT=A5X/.09290304
      TTT=((TT3*1.8)/1000.)**2.
      BSV=(WA)*TTT)/THROAT
      IF (I2.EQ.1) CALL ETA
      TT4=ETAC*(TT4I-TT3)+TT3
      BBB=2.0*R*(1.0+GAMMA4)*TT4/GAMMA4
      BBB=AMAX1(400.,BBB)
      SA=(1.0+FAR)*SQRT(BBB)
      SART=SA/SQRTOT
  169 CONTINUE
C
C     CMMENT  MAKE CALCULATIONS TAKING VARIABLE NOZZLE GAMMA INTO EFFECT
C
      A4OA5=A4/A5
      M4=FMARL(GAMMA4,A4OA5)
      PHI4=PHIM(GAMMA4,M4)
C
C      ******** WE COMPUTE CONDITIONS AT STATION 3 HERE ********
C
      STROG=23.9613
      IF (I1.EQ.1) GO TO 170
C     RAMJET COMPUTATIONS - FUEL ADDED IN THE INLETS
      SARTA=STROG*SQRT((GAMMA3+1.)/GAMMA3)*(1.+FAR)
      PHI3=(PHI4*SART/SARTA)+((GAMMA3*CDB*M3*M3)/(2.*XMCIR3*SARTA))
      GO TO 180
C     GAS GENERATOR SYSTEM COMPUTATIONS
  170 SARTB=STROG*SQRT((GAMMA3+1.)/GAMMA3)
      PHI3=(PHI4*SART/SARTB)-((PHIPRI*ISTAR*FAR)/(SARTB*SQRTOT))+((GAMMA
     13*CDB*M3*M3)/(2.*XMCIR3*SARTB))
  180 CONTINUE
      M3=FMPHIM(GAMMA3,PHI3)
```

```
      FMCFT3=FFMCFT(GAMMA3,M3)
      PMOPT=FFMCPT(1.4,M)
      XMCIF3=FMCIR(GAMMA3,M3)
C
C      ******** WE NOW CALL THE INLET ROUTINE TC GET WA ********
C
      CALL HCF
C
  190 CONTINLE
C
C      ******** DEBUG OUTPLT ********
C
      IF (I7.EC.0) GO TC 2CC
  201 CONTINLE
      FK=F/10CC.
      P1K=P1/1CCC.
      F2K=F2/1000.
      P3K=P3/1CCC.
      P4K=P4/10CC.
      F5K=F5/1000.
      P6K=P6/1C0C.
      FTK=PT/1C00.
      FT1K=PT1/10C0.
      PT2K=PT2/1CCC.
      FT3K=PT3/1000.
      PT4K=PT4/10C0.
      PT5K=PT5/10CC.
      PT6K=FT6/1000.
      QK=Q/1CCC.
      WRITE (6,250) A,AINF,A1,A2,A3,A4,A5,A6,AR,AFR,AFS,ALPHA
      WRITE (6,260) ACR,BLEEC
      WRITE (6,27C) CDASUB,CDASUP,CDB,CF,CFINF,CF6,CFB,CFT,CFC,CNM
      WRITE (6,280) ER,ERRL,ERLL,ETAC,ETAN,F
      WRITE (6,290) FAR,G,GAMMA,GAMMA1,GAMMA2,GAMMA3,GAMMA4,GAMMA5,GAMMA
     16
      WRITE (6,300) H,ISP,ISTAR,I1,I2,I3,I4,I5,I6,I7,I8,I9,I10
      WRITE (6,31C) COUNT,ICCNV,ICONVP,IFIRST
      WRITE (6,320) M,M1,M2,M3,M4,M5,M6,MW,MW1,MW2,MW3,MW4,MW5,MW6
      WRITE (6,330) MACR,MACRS,PM
      WRITE (6,340) PK,P1K,P2K,P3K,P4K,P5K,P6K,PT3CI,PRAR
      WRITE (6,350) PTK,PT1K,PT2K,PT3K,PT4K,PT5K,PT6K,PMOPT,PMCPT1,PMCFT
     12,PMCPT3
      WRITE (6,360) PHI1,PHI2,PHI3,PHI4,PHI5,PHI6,PHIPRI,QK
      WRITE (6,370) RADEG,F,SA,SART,SQRTOT
      WRITE (6,380) T,T1,T2,T3,T4,T5,T6,TIME
      WRITE (6,390) TT,TT1,TT2,TT3,TT4,TT5,TT6
      WRITE (6,400) V,V1,V2,V3,V4,V5,V6
      WRITE (6,410) WA,WF,X,Y,Z
```

```
C
C
  20C CONTINLE
C     SET IFTS, INCREASE CCUNT AND CALCULATE PARAMETERS NOT IN COMMON
C
      COLNT=CCLNT+1
C
C     CHECK CCNVERGENCE, ICCNVF IS USED TO MAKE SCLUTICN CONVERGE TWICE
C     IF CCNVERGEC, PRINT.  IF NOT, GO BACK AND TRY AGAIN
C
      IF (IFIRST.EC.-1) GC TC 225
      IF (ICCNV+ICCNVP) 21C,22C,210
  21C ICCNVF=ICCNV
      GO TC 4C
  220 CONTINLE
C      ******** WE NOW COMFLTE THRUST IF CCNVERGEC ********
C
      A6CA5=A6/A5
      M6=FMARH(GAMMA4,A6CA5)
      PHI6=PHIM(GAMMA4,M6)
      IF(I10.GE.5) GO TC 221
      CF6=(WA*SA*PHI6*ETAN-A6*F)/(AR*Q)
  221 CCNTINLE
      CFINF=2.C*ACR*MACRS*A1/AR
      CALPHA=CCS(ALPHA/RACEG)
      CF=CF6-(CFINF*CALPHA)+CFB+CFC
      F=CF*C*AR
      IF(WF.EC.0.0) GO TO 1300
      ISP=F/(WF*G)
      GO TC 15CC
 130C ISP=C.C
 1500 CCNTINLE
      G1=GAMMA4+1.C
      G2=GAMMA4-1.0
      G3=G1/G2
      G4=2.*G1*((2./G1)**G3)
      G5=SCRT(G4)
      PT5=(SA*WA)/(G5*A5)
C
C      PREPARE CATA FOR TRANSFER TO MAIN PROGRAM
C
  225 CONTINLE
      HIN=H
      XMIN=M
      AIN=ALPHA
      WFIN=WF
      CDADC=CCASUB+CDASUP+CFT
      CT=CF-CCACC
```

```
      SMARG=FN
      IFI=IFIRST
      FCOUNT=COUNT+.01
      WRIT(1)=PT3CI
      WRIT(2)=WA
      WRIT(3)=TT4
      WRIT(4)=MACR
      WRIT(5)=ACR
      WRIT(6)=ER
      WRIT(7)=ISP
      WRIT(8)=FCOUNT
      WRIT(9)=WF
      WRIT(10)=ETAC
      WRIT(11)=CT
      WRIT(12)=FN
      WRIT(13)=FCOUNT
      WRIT(14)=ESV
      IF(PT3.EQ.0.0) GO TO 1200
      WRIT(15)=PT5/PT3
 1200 CONTINUE
      WRIT(16)=PT5/1000.
      FCOUNT=FCOUNT
      RETURN
C
  230 FORMAT ('      COMPUTE PHI3')
  240 FORMAT ('      I5 IS OUT OF RANGE-WHY')
  250 FORMAT (1H1,F8.2,8F7.4,2F7.3,F7.2)
  260 FORMAT (2F8.5)
  270 FORMAT (10F8.5)
  280 FORMAT (5F8.5,F10.3)
  290 FORMAT (9F8.5)
  300 FORMAT (F9.2,2F8.3,10I2)
  310 FORMAT (4I4)
  320 FORMAT (7F7.4,7F8.4)
  330 FORMAT (2F9.5,F7.3)
  340 FORMAT (7F10.2,2F7.5)
  350 FORMAT (7F10.2,4F7.5)
  360 FORMAT (7F8.5,F10.2)
  370 FORMAT (F9.5,2F10.5,2F8.5)
  380 FORMAT (8F10.3)
  390 FORMAT (7F10.3)
  400 FORMAT (7F10.3)
  410 FORMAT (2F8.3,3F10.5)
  420 FORMAT (54H1  AIR BREATHING ENGINE GEOMETRY                      )
  430 FORMAT (14H         A 1  = F9.7,9H SQ METRE)
  440 FORMAT (14H         A 3  = F9.7,9H SQ METRE)
  450 FORMAT (14H         A 4  = F9.7,9H SQ METRE)
  460 FORMAT (14H         A 5  = F9.7,9H SQ METRE)
```

```
  470 FCRMAT (14H        A 6   = F9.7,9H SQ METRE)
  48C FORMAT (14H        A R   = F9.7,9H SQ METRE)
  49C FORMAT (28H        PHI4                  = F7.5)
  5CC FORMAT (28H        PHI6                  = F7.5)
  510 FORMAT (28H        BURNER DRAG COEFF. = F6.2)
  520 FORMAT (28H        NCZZLE MASS COEFF. = F6.2)
  53C FORMAT (36H DID NOT CCNVERGE AFTER 100 ATTEMPTS)
  540 FORMAT (47H0    RAMJET PROPULSION                          )
C
      END
C
C
C
      SUBRCUTINE ETA
C
C
C     NWC COMMCN DECK FCR AIRBREATHING PROPULSICN PROGRAMS
C     CPIA NCMENCLATURE
C
      REAL ISP,ISTAR,M,M1,M2,M3,M4,M5,M6,MW,MW1,MW2,MW3,MW4,MW5,MW6
      REAL MACR,MACRS
      INTEGEF CCUNT
C
      COMMCN /RJ/ A,AINF,A1,A2,A3,A4,A5,A6,AR,AFR,AFS,ALPHA
      COMMCN /RJ/ ACR,BLEEC
      COMMON /RJ/ CDASUB,CCASUF,CDB,CF,CFINF,CF6,CFB,CFT,CFC,CNM
      CCMMCN /FJ/ ER,ERRL,ERLL,ETAC,ETAN,F
      COMMCN /RJ/ FAR,G,GAMMA,GAMMA1,GAMMA2,GAMMA3,GAMMA4,GAMMA5,GAMMA6
      COMMCN /RJ/ H,ISP,ISTAR,I1,I2,I3,I4,I5,I6,I7,I8,I9,I10
      CCMMCN /FJ/ CCUNT,ICCNV,ICONVP,IFIRST
      COMMCN /RJ/ M,M1,M2,M3,M4,M5,M6,MW,MW1,MW2,MW3,MW4,MW5,MW6
      COMMCN /RJ/ MACR,MACRS,PM
      COMMCN /RJ/ P,P1,P2,P3,P4,P5,P6,PT30I,PRAR
      COMMCN /RJ/ PT,PT1,PT2,PT3,PT4,PT5,PT6,PMOPT,PMOPT1,PMOPT2,PMCPT3
      COMMCN /RJ/ PHI1,PHI2,PHI3,PHI4,PHI5,PHI6,PHIPRI,Q
      COMMCN /RJ/ RADEG,R,SA,SART,SQRTOT
      COMMCN /RJ/ T,T1,T2,T3,T4,T5,T6,TIME
      COMMCN /RJ/ TT,TT1,TT2,TT3,TT4,TT5,TT6
      COMMCN /RJ/ V,V1,V2,V3,V4,V5,V6
      COMMCN /RJ/ WA,WF,X,Y,Z
C
C
      CATA A11,B11,C11,D11,E11,F11,G11
     * /-1407.68, .95416, -8.59033, 43.7266, 1468.91, 80484.,
     * -277056./
C
      FAR2=FAR*FAR
      FOVER=1./(1.+FAR)
```

```
      TERM1=B11+C11*FAR+D11*FAR2
      TERM2=E11+F11*FAR+G11*FAR2
      TTR=1.8*TT
      TT4I=A11+TTR*TERM1+FCVER*TERM2
      STT4I=SQRT(TT4I)
      ETAC=40.246*STT4I-0.3513*TT4I-1055.08
      ETAC=ETAC/1CC.
      IF(ER.LT. .0001) ETAC=0.0
      RETURN
      END
C
C
C
      SUBROUTINE HCRA
C
      DIMENSICN PS(66), PSTAT1(11), FUELF(11)
C
C
C     NWC CCMMCN DECK FOR AIRBREATHING PROPULSION PROGRAMS
C     CPIA NCMENCLATURE
C
      REAL ISP,ISTAR,M,M1,M2,M3,M4,M5,M6,MW,MW1,MW2,MW3,MW4,MW5,MW6
      REAL MACR,MACRS
      INTEGER CCUNT
C
      COMMCN /RJ/ A,AINF,A1,A2,A3,A4,A5,A6,AR,AFR,AFS,ALPHA
      COMMCN /RJ/ ACR,BLEED
      COMMCN /RJ/ CDASUB,CDASUF,CDB,CF,CFINF,CF6,CFB,CFT,CFC,CNM
      CCMMCN /RJ/ ER,ERRL,ERLL,ETAC,ETAN,F
      COMMCN /RJ/ FAR,G,GAMMA,GAMMA1,GAMMA2,GAMMA3,GAMMA4,GAMMA5,GAMMA6
      COMMCN /RJ/ H,ISP,ISTAR,I1,I2,I3,I4,I5,I6,I7,I8,I9,I10
      CCMMCN /RJ/ CCUNT,ICCNV,ICCNVP,IFIRST
      COMMCN /RJ/ M,M1,M2,M3,M4,M5,M6,MW,MW1,MW2,MW3,MW4,MW5,MW6
      COMMCN /RJ/ MACR,MACRS,PM
      COMMCN /RJ/ P,P1,P2,P3,P4,P5,P6,PT30I,PRAR
      COMMCN /RJ/ PT,PT1,PT2,PT3,PT4,PT5,PT6,PMOPT,PMOPT1,PMOPT2,PMOPT3
      CCMMCN /RJ/ PHI1,PHI2,PHI3,PHI4,PHI5,PHI6,PHIPRI,Q
      COMMCN /RJ/ RADEG,R,SA,SART,SQRTOT
      COMMCN /RJ/ T,T1,T2,T3,T4,T5,T6,TIME
      CCMMCN /RJ/ TT,TT1,TT2,TT3,TT4,TT5,TT6
      COMMCN /RJ/ V,V1,V2,V3,V4,V5,V6
      COMMCN /RJ/ WA,WF,X,Y,Z
C
C
C     ANGLE CF ATTACK   PS(I) I=3,14
C     MACH NUMBER       PS(I) I=15,81
C
      DATA PS/
```

```
     A12.0,4.0,0.0,0.5,1.0,1.5,2.0,
     A2.5,3.0,4.0,5.0,6.0,7.0,8.0,
     A1.5,2.0,2.5,3.0,
     A .98407,.93504,.89727,.88386,
     A .98069,.93504,.89727,.88386,
     A .97828,.93504,.89689,.88275,
     A .97586,.93410,.89463,.88165,
     A .97345,.93295,.89313,.87833,
     A .97056,.93039,.89087,.87501,
     A .96815,.92808,.88711,.87058,
     A .96320,.92158,.87733,.85842,
     A .95704,.91044,.86076,.84183,
     A .94068,.89257,.83781,.81749,
     A .94111,.87331,.81185,.78210,
     A .92905,.85267,.79190,.75666/
C
      DATA FSTAT1/3.07,3.9,4.9,6.02,7.,8.,9.1,10.,11.,12.,13.18/
C
      DATA FUELF/.94,1.130,1.375,1.628,1.859,
     A 2.056,2.250,2.416,2.562,2.722,3.05/
C
      IF (IFIRST) 10,20,20
   10 CONTINUE
      WRITE (6,50)
      RETURN
   20 CONTINUE
      IF (COUNT-1) 30,30,40
   30 CONTINUE
      CALL INTR2C (ALPHA,M,PS1CP,PS,1)
      FS1=PS1CP*(P/6894.757)
      TFFPS=CDLI(FS1,PSTAT1,FUELF,11)
      TFF=TFFPS*.4535924
      WF=TFF
   40 RETURN
C
   50 FORMAT (T6,'FUEL CONTROL FOR STV G      ')
C
      END
C
C
C
      SUBROUTINE HCF
C
      DIMENSION PR(81), AA(81), CADD(12), XM(12), BWR(12)
C
C     NWC COMMON DECK FOR AIRBREATHING PROPULSION PROGRAMS
C     CPIA NOMENCLATURE
C
```

```
      REAL ISP,ISTAR,M,M1,M2,M3,M4,M5,M6,MW,MW1,MW2,MW3,MW4,MW5,MW6
      REAL MACR,MACRS
      INTEGER COUNT
C
      COMMON /RJ/ A,AINF,A1,A2,A3,A4,A5,A6,AR,AFR,AFS,ALPHA
      COMMON /RJ/ ACR,BLEED
      COMMON /RJ/ CDASUB,CDASUP,CDB,CF,CFINF,CF6,CFB,CFT,CFC,CNM
      COMMON /RJ/ ER,ERRL,ERLL,ETAC,ETAN,F
      COMMON /RJ/ FAR,G,GAMMA,GAMMA1,GAMMA2,GAMMA3,GAMMA4,GAMMA5,GAMMA6
      COMMON /RJ/ H,ISP,ISTAR,I1,I2,I3,I4,I5,I6,I7,I8,I9,I10
      COMMON /RJ/ COUNT,ICONV,ICONVP,IFIRST
      COMMON /RJ/ M,M1,M2,M3,M4,M5,M6,MW,MW1,MW2,MW3,MW4,MW5,MW6
      COMMON /RJ/ MACR,MACRS,PM
      COMMON /RJ/ P,P1,P2,P3,P4,P5,P6,PT30I,PRAR
      COMMON /RJ/ PT,PT1,PT2,PT3,PT4,PT5,PT6,PMOPT,PMOPT1,PMOPT2,PMOPT3
      COMMON /RJ/ PHI1,PHI2,PHI3,PHI4,PHI5,PHI6,PHIPRI,Q
      COMMON /RJ/ RADEG,R,SA,SART,SQRTOT
      COMMON /RJ/ T,T1,T2,T3,T4,T5,T6,TIME
      COMMON /RJ/ TT,TT1,TT2,TT3,TT4,TT5,TT6
      COMMON /RJ/ V,V1,V2,V3,V4,V5,V6
      COMMON /RJ/ WA,WF,X,Y,Z
C
C
C     PRESSURE RECOVERY INSTALLED ALVJ -- BETA=0.0  (PS(I) I=19,81)
C
      DATA PR/
     A9.0,7.0,0.0,0.9,1.0,1.5,2.2,
     A2.43,2.7,3.1,4.0,0.0,1.0,2.0,
     A4.0,6.0,8.0,10.0,
     A .9500,.9475,.9450,.9400,.9250,.8775,.8320,
     A .9500,.9475,.9450,.9400,.9250,.8775,.8320,
     A .9500,.9475,.9450,.9400,.9250,.8775,.8320,
     A .9400,.9375,.9350,.9300,.9100,.8600,.8150,
     A .7675,.7660,.7640,.7600,.7430,.7000,.6575,
     A .6980,.6860,.6840,.6800,.6350,.5750,.5275,
     A .5400,.5375,.5350,.5300,.4925,.4300,.3800,
     A .3800,.3760,.3725,.3650,.3400,.2850,.2400,
     A .2000,.1960,.1925,.1850,.1600,.1050,.0800/
C
C
C     AIR CAPTURE INSTALLED ALVRJ DEC 1975  AA(I) I=19,81
C
      DATA AA/
     A9.0,7.0,0.0,0.9,1.0,1.5,2.2,
     A2.43,2.7,3.1,4.0,0.0,1.0,2.0,
     A4.0,6.0,8.0,10.0,
     A .9465,.9457,.9452,.9440,.9400,.9350,.9270,
     A .9465,.9457,.9452,.9440,.9400,.9350,.9270,
```

```
     A .5825,.5819,.5812,.5800,.5700,.5650,.5050,
     A .6725,.6712,.6700,.6675,.6520,.6400,.6275,
     A .9010,.9000,.8990,.8970,.8725,.8550,.8350,
     A .9425,.9400,.9375,.9325,.9200,.9075,.8950,
     A .9450,.9425,.9410,.9375,.9300,.9225,.9125,
     A .9450,.9437,.9425,.9400,.9370,.9325,.9250,
     A .9450,.9437,.9425,.9400,.9370,.9325,.9250/
C
C
      DATA XN/
     A  .5,.9,1.,1.4,1.6,2.2,2.43,2.48,2.5,2.7,3.0,3.25/
C
      DATA CACD/
     A .0213,.0213,.0132,.125,.0988,.0221,.0184,.0173,.0171
     B ,.0123,.0149,.0176/
C
      DATA BWR/
     A .0339,.0339,.0208,.0237,.0249,.0334,.0287,.0265,.0259,
     B .0213,.0171,.0150/
C
      IF (IFIRST) 10,20,20
   10 CONTINUE
      PRAR=0.0
      TOL=.0004
      WRITE (6,100) TOL
      RETURN
C
C
   20 CONTINUE
C
C SET PRESENT PR/AR EQUAL TO PREVIOUS PR/AR
C
      PRARP=PRAR
C
C CALCULATE NEW PR/AR
C
      TT=T/FTOTT(1.4,M)
      TTRATO=SQRT(TT3/TT)
      PRAR=TTRATO*PMOPT*MACRS*A1/(PMOPT3*A3)
      IF (IBC.EQ.0) PRAR=TTRATO*PMOPT*MACRS*A1*(1.0+FAR)/(PMOPT3*A3)
C
C CHECK FOR CONVERGENCE BY COMPARING PR/AR TO PREVIOUS PR/AR
C
      IF (ABS(PRARP-PRAR)-TOL) 40,40,30
   30 ICONV=1
   40 CONTINUE
      CALPHA=COS(ALPHA/RADEG)
C
```

```
C
C     COMPUTE CRITICAL PRESSURE RECOVERY AND MAXIMUM AIR CAPTURE RATIO
C
      ALPHAB=ABS(ALPHA)
      CALL INTR20 (M,ALPHAB,MACR,AA,1)
      BLDTS=CDLI(M,XM,BWR,12)
      BLDDB=.015
      BLEED=BLDTS+BLDDB
      MACRS=MACR*(1.0-BLEED)
      CALL INTR20 (M,ALPHAB,PRIAD,PR,1)
C
C     CRITICAL PRESSURE RECOVERY
C
      PACR=PRIAD
      IF (PRAR-PACR) 50,60,70
C
C     PRESSURE RECOVERY  .LT. CRITICAL
C
   50 PT3OI=PRAR
      ACR=1.
      GO TO 80
C
C     PRESSURE RECOVERY  .EQ. CRITICAL
C
   60 PT3OI=PRIAD
      ACR=1.
      GO TO 80
C
C     PRESSURE RECOVERY  .GT. CRITICAL --CHANGE AIR CAPTURE AND SET PRES
C     RECOVERY EQUAL TO CRITICAL VALUE
C
   70 PT3OI=PRIAD
      ACR=PRIAD/PRAR
   80 POPT=PFOPT(1.4,M)
      PT=P/POPT
      PT3=PT*PT3OI
      PM=(PRIAD-PT3OI)/(PRIAD/100.)
      AINF=ACR*A1*MACRS
      SQTINF=SQRT(TT)
      WA=(AINF*PT*PMOPT)/SQTINF
      IF(ICONVF.NE.0 .OR. ICONV.EQ.1) RETURN
      CDSUB=0.0
      IF (PRAR.LE.PACR) GO TO 90
C
C     CALCULATE ADDITIVE DRAG DUE TO SUBSONIC SPILLAGE
      ETASUB=M/((M*10.2095)-11.5652)
      CDSUB=2.*(1.-ETASUB)*(1.-ACR)
C
```

```
C      CALCULATE ADDITIVE DRAG DUE TO SUPERSONIC SPILLAGE
C
   90  CAED=CDLI(M,XM,CADD,12)
       IF (PRAR.LE.PACR) CDSUB=0.0
       CDASUB=CDSUB*A1/AR
       CDASUP=CAED
       CFB=0.0
C                             CFT IS RAT DRAG
       CFT=0.0032
        PESI=2.14678-1.11439*M+.22989*M*M
       PE=PESI*P
       AINFB=A1*BLDCB
       AE=9.33*.00064516
       TRM1=P*AINFB*1.4*M*M
       TRM2=P*AE
       WDOT=(FT*AINFB*PMOPT)/SQTINF
       XMOE=WDOT*SQRT(TT-222.)/(PE*AE)
       XME=FROM(1.4,XMOE)
       TRM3=PE*AE*(1.+1.4*XME*XME)
       CFC=-((TRM1+TRM2-TRM3)/(Q*AR))
       RETURN
C
 100   FORMAT (T6,'ALVRJ INLET DATA DEC 1975 ,TOL=',F7.6)
C
       END
C
C
C
       FUNCTION INTRP (AH,AL,BH,BL,FH,FM)
C
       REAL INTRP
       C2 = AL + (AH - AL)*FM
       C1 = BL + (BH - BL)*FM
       INTRP = C1 + (C2 - C1)*FH
       RETURN
       END
C
C
C
       FUNCTION FATAS(GAM,XM)                                          FATA0030
C
CFATAS     FUNCTION SUBPROGRAM TO CALCULATE A OVER ASTAR              FATA0010
C          FROM GAMMA AND MACH NUMBER                                   FATA0020
C
       Z=(GAM+1.0)/(2.0*(GAM-1.0))                                     FATA0040
       A=2.0/(GAM+1.0)                                                 FATA0050
       B=(GAM-1.0)/2.0                                                 FATA0060
       C=1.0/XM                                                        FATA0070
```

```
      D=A*(1.C+(E*XM*XM))                                             FATA008C
      FATAS=C*(D**Z)                                                  FATA009C
      RETURN                                                          FATA0100
      END                                                             FATA011C
C
C
C
      FUNCTICN FIXAC (A)                                              R    2
C
      TFIX=AES(A)-1.0000005                                           R    4
      IF (TFIX.LT.0.0) GO TC 1C                                       R    6
   10 IF (A.LT.0.0) GO TC 20                                          R    8
      FIXAC=C.C                                                       R   10
      GO TC 3C                                                        R   12
   20 FIXAC=3.14159265                                                R   14
   3C CONTINLE                                                        R   16
      RETURN                                                          R   18
      END                                                             R   20-
C
C
C
      FUNCTICN FIXAS (A)                                              S    2
C
      TFIX=AES(A)-1.0000005                                           S    4
      IF (TFIX.LT.0.0) GC TC 10                                       S    6
   10 IF (A.LT.0.0) GO TO 20                                          S    8
      FIXAS=1.57079633                                                S   10
      GO TC 3O                                                        S   12
   20 FIXAS=-1.57079633                                               S   14
   3C CCNTINLE                                                        S   16
      RETURN                                                          S   18
      END                                                             S   20-
C
C
C
      FUNCTICN  FMARH (GAM,ATAS)                                      FMAR0030
C
CFMARH          FUNCTION SUBPRCGRAM TO CALCULATE MACH NUMBER          FMAR001C
C                           FRCM ATAS AND GAMMA                       FMAR002C
C
      Z = (GAM + 1.0) / (2.C*(GAM - 1.0))                             FMAR0040
      DXMG = 10.0                                                     FMAR005C
      XMG = 10.C                                                      FMAR006C
  5CC DXMG = DXMG / 2.0                                               FMAR0070
      XMG= AMAX1(1.0,AMIN1(100.0,XMG))                                FMAR008C
      IF(DXMG - .C000015)1CC,1C0,200                                  FMAR0090
  200 CATAS = 1.0/XMG*((2.0+ (GAM - 1.0) *XMG **2 )/(GAM + 1.0))**Z   FMAR0100
      IF(CATAS - ATAS)700,100,800                                     FMAR011C
```

```
  70C XMG = XMG + DXMG                                                   FMAR0120
      GO TO 50C                                                          FMAR0130
  80C XMG = XMG - DXMG                                                   FMAR0140
      GO TO 500                                                          FMAR0150
  10C FMARF = XMG                                                        FMAR0160
      RETURN                                                             FMAR0170
      END                                                                FMAR0180
C
C
C
      FUNCTION FMARL(GAM,AR)
C
C      FUNCTION ROUTINE TO FIND MACH FROM A/A* AND GAMMA
C      USING NEWTONS METHOD FOR FINDING ROOTS OF AN EQUATION
C
C      SUBSONIC SOLUTION
      IF(GAM.LT.1.) WRITE(6,30)
      IF(AR.LT.1.) WRITE(6,40)
      IF(GAM.LT.1. .OR. AR.LT.1.) CALL EXIT
      GM1=GAM-1.
      GP1=GAM+1.
      A=2./GP1
      B=GM1/GP1
      Z=GP1/(2.*GM1)
      IF(AR.LT.1.3401) XMP=2.4706-(1.47059*AR)
      IF(AR.GT.1.34 .AND. AR.LT.3.001) XMP=.77443-(.2048*AR)
      IF(AR.GT.3.) XMP=(A**Z)/AR
      TOL=.0001
   10 CONTINUE
      BRACK=A+(B*XMP*XMP)
      POWER=BRACK**Z
      TOP=(1./XMP)-(AR/POWER)
      BOTTOM=(1./BRACK)-(1./(XMP*XMP))
      XM=XMP-(TOP/BOTTOM)
      DELTA=ABS(XM-XMP)
      XMP=XM
      IF(DELTA.GT.TOL) GO TO 10
C
      FMARL=XM
C
      RETURN
C
   30 FORMAT('GAMMA LT 1 IN FMARL')
   40 FORMAT('A/A* LT 1 IN FMARL')
C
      END
C
C
```

```
C
      FUNCTION  FMPHIM  (GAM , PHI )                                    FMPH0020
C
CFMPHIM    FUNCTION SUBPROGRAM TO CALC MACH NO  FROM PHIM               FMPH001C
C
      TOL = .CC001                                                      FMPH003C
      XMSN = 1.0 / ( PHI**3 )                                           FMPH0040
  127 X = XMSN                                                          FMPH005C
      XMSN = (1.C + (GAM*(XMSN**2))) / (PHI * SCRT(2.0 * (GAM+1.0)*(1.0 FMPH0060
     1+(GAM-1.0)*.5*(XMSN**2)))))                                       FMPH0070
      XMSN= AMAX1(0., AMIN1(1.C,XMSN))
      IF (ABS(X-XMSN)-TOL ) 125, 125, 128                               FMPH0090
  128 XMSN = (X + XMSN) / 2.0                                           FMPH010C
      GO TC 127                                                         FMPH011C
  125 FMPHIM = XMSN                                                     FMPH0120
      RETURN                                                            FMPH013C
      END                                                               FMPH0140
C
C
C
      FUNCTION  FMPOPT (GAM,POPT)                                       FMP00030
C
CFMPOPT   FUNCTION  SUBPROGRAM TO CALC  XMACH                           FMP0001C
C                   FROM  P/PT AND GAMMA                                FMP00020
C
      Z =  (PCPT) ** ((1.C- GAM)/ GAM)                                  FMP0004C
      SMPPT =  ( Z - 1.0)/(GAM - 1.0) * 2.0                             FMP00050
      FMPCPT = SCRT(SMPPT)                                              FMP0006C
      RETURN                                                            FMP0007C
      END                                                               FMP00080
C
C
C
      FUNCTION PHIM (GAM, XMCH)                                          FHI002C
C
C PHIM  FUNCTION  TO CALC PHI FROM GAMMA AND MACH                        FHI0010
C
      PHIM = (1.0+GAM *(XMCH **2)) /(XMCH  * SQRT(2.0*(GAM + 1.0)*(1.0+  FHI003C
     1 .5 *(GAM -1.0) * (XMCH **2))))                                    FHI004C
      RETURN                                                             FHI005C
      END                                                                FHI0060
C
C
C
      FUNCTION  FPOPT (GAM,XMACH)                                        FP00030
C
C FPOPT    FUNCTION  SUBPROGRAM TO CALC TOTAL PRESSURE RATIO             FP0001C
C               FROM GAMMA AND MACH NO.                                  FP0002C
```

```
C
      Z = -GAM /(GAM - 1.0)                                                FP00040
      FPOPT  =     (1.0+.5*(GAM -1.0)*(XMACH**2))**Z                        FP00050
      RETURN                                                               FP00060
      ENC                                                                  FP00070
C
C
C
      FUNCTICN FRCM(GAM,XMCIR)
C
C     FUNCTICN ROUTINE TO COMPUTE MACH NUMBER FROM
C     MCIRCLE AND GAMMA FCR ALL MACH NUMBERS USING NEWTONS METHOD
C
      IF (GAM.LT.1.) WRITE (6,100)
      IF (GAM.LT.1.) CALL EXIT
      A=GAM
      B=0.5*GAM*(GAM-1.)
      C=XMCIR/.C5902063
      XMP=C/(1.18+(.0923*C))
      TCL=.0001
   1C CONTINLE
      BRACK=A+(B*XMP*XMP)
      POWER=SCRT(BRACK)
      TOP=(XMP*PCWER)-C
      BOTTCM=(A+(2.*B*XMP*XMP))/POWER
      XM=XMP-(TCP/BCTTOM)
      CELTA=ABS(XM-XMP)
      XMP=XM
C
      IF(DELTA.GT.TOL) GO TC 1C
C
      FRCM=XM
C
      RETURN
C
  100 FORMAT('GAMMA LT 1 IN FROM')
      END
C
C
C
      FUNCTICN FTCTT  (GAM,XMACH)                                          FT00020
C
C FTCTT   FUNCTICN SUBPROGRAM TO CALC  T/TT    FROM    GAMMA AND MACH NC FT00010
C
      FTOTT   =  (1.0+.5*( GAM-1.0)*(XMACH**2))**(-1.0)                    FT00030
      RETURN                                                               FT00040
      END                                                                  FT00050
C
```

```
C
C
      SUBROUTINE TAB(FAS)
C
      WRITE(6,15)
   15 FORMAT (T6,'NO.2 JP5 AND JETA FUEL MAY 1,1976 ONE ATM          ')
      FAS=   14.6394
      RETURN
      END
C
C
C
      FUNCTION FMCIR (GAM,XM)
C
C MCIRCLE      FUNCTION SUBPROGRAM TO CALC MCIR FROM GAMMA AND MACH NO
C         R AIR= 8314.34/28.96246 = 287.073 N M/ KG K
C        M CIRCLE DIMENSIONS = SEC * SQRT(K) / METRE
C
      FMCIR=.0590206289*XM*SQRT(GAM*(1.0+((GAM-1.0)/2.0)*XM**2))
      RETURN
      END
C
C
C
      SUBROUTINE AIR (Z,V,J,P,T,S,D,Q,GO,K,KK)
C
C     Z=ALTITUDE IN METERS
C     V=MACH NUMBER OR VELOCITY, SEE KK
C     J=FIRST PASS IDENTIFIER SWITCH, -=FIRST PASS AND +=NOT FIRST PASS
C     P=PRESSURE IN PASCALS OR PSI
C     T=TEMPERATURE IN K OR R
C     S=SPEED OF SOUND IN METERS/SEC OR FT/SEC
C     D=DENSITY IN KG/CUBIC METER OR LBM/CUBIC FOOT
C     Q=DYNAMIC PRESSURE IN PA OR PSI
C     GO=LOCAL GRAVITY IN FT/SEC2 OR METERS/SEC2
C     K=1, SI UNITS
C     K=2, ENGLISH UNITS
C     KK=1, V IS MACH NUMBER
C     KK=2, V IS VELOCITY, METERS/SEC OR FT/SEC
C
      DIMENSION A(2,16), C(15)
C
C **                A(1,J),J=1,16
C **  THESE ARE THE CHEBYSHEV COEFFICIENTS FOR P/PO
C
C **                A(2,J),J=1,16
C **  THESE ARE THE CHEBYSHEV COEFFICIENTS FOR D/DO
C
```

```
      CATA A/
     A-4.4038210, -4.013517C, -2.2874890, -2.1765372,
     B -.0494300, -.1358554,    .0355105,   .0498002,
     C -.0055258,   .0061961, -.0030910,  -.0121108,
     D  .0026116,   .0029277, -.0004221,   .C044266,
     E -.0C1C261,  -.0039804,   .0007523,  -.0013126,
     F  .0C03149,   .0033573, -.0005513,  -.001147,
     G -.0000031,  -.0021286,   .0002918,   .0008523,
     H -.0001420,   .0010109,   .99998983, 1.0000000/
C
C **  SET CCNSTANTS
C
      CATA PC,CC,RBAR,GC,Z1/
     *   101325.0,1.225,287.07299,9.80665,30480.0/
C
C **  IF NECESSARY , CONVERT TC SI UNITS
C                            Z BECCMES METERS
C                            V BECCMES METERS/SEC
C
      IF (K.EC.2) Z=Z*.3048
      IF (K.EC.2.AND.KK.EC.2) V=V*.3048
C
C **  START HERE
C
      IF (J) 10,20,20
   1C WRITE (6,6C)
      WRITE (6,7C) Z1
C
C **  CCMPLTE C(K) COEFFICIENTS
C
   2C ETA=2.*(2.*Z/Z1-1.)
      C(1)=ETA
      C(2)=ETA**2-2.
      CO 3C I=3,15
   3C   C(I)=ETA*C(I-1)-C(I-2)
C
C **  CCMPLTE CHEBYSHEV TRUNCATED EXPANSION
C
      ALNP=A(1,1)
      ALND=A(2,1)
      CO 4C I=2,15
        ALNP=ALNP+A(1,I)*C(I-1)
   4C   ALNC=ALND+A(2,I)*C(I-1)
C
C **  CCMPLTE ATMCSPHERIC PRESSURE
C                            P IN N/SQ METER
C
      ALNP=.5*ALNP
```

```
      POPZ=EXP(ALNP)
      P = POPZ*PO*A(1,16)
C
C **  COMPUTE GRAVITY AT ALTITUDE AND LATITUDE
C                         RO IS EQUATORIAL RADIUS (M) PER CRC HANDBOOK
C                         GO IN M/SEC SQ
C
      RO=6378377.45
      GO=GO*((RO/(RO+Z))**2)
C
C **  COMPUTE ATMOSPHERIC DENSITY
C                         D IN KG PER CUBIC METRE
C
      ALND=.5*ALND
      DODZ=EXP(ALND)
      D = DODZ*DO*A(2,16)
C
C **  COMPUTE AIR TEMPERATURE
C                         T IN DEGREE KELVIN
C
      T=P/(REAR*D)
C
C **  COMPUTE SPEED OF SOUND IN M/SEC
C
      S=SQRT(401.90219*T)
C
C **  COMPUTE DYNAMIC PRESSURE IN PA
C
      IF (KK.EQ.1) Q=0.7*P*V**2
      IF (KK.EQ.2) Q=0.7*P*(V/S)**2
C
C **  CONVERT TO ENGLISH UNITS IF NECESSARY
C
      IF (K.EQ.1) GO TO 50
      Z=Z/.3048
      IF(KK.EQ.2) V=V/.3048
      P=P/6894.757
      T=T*1.8
      S=S/.3048
      D=D/16.01846
      Q=Q/6894.757
      GO=GO/.3048
   50 RETURN
  60  FORMAT (T9,'*** US 1962 STANDARD ATMOSPHERE')
  70  FORMAT (T9,'*** ALTITUDE FROM 0 TO ',F8.0,' METERS')
      END
C
C
```

```
C
      FUNCTION ANORM(A,B)
C
C     CALCULATES TOTAL PRESSURE RATIO ACROSS A NORMAL SHOCK
C     A=GAMMA,B=XMACH
C
      C=(A+1.)/2.
      D=(A-1.)/2.
      E=(2.*A)/(A+1.)
      F=(A-1.)/(A+1.)
      G=A/(A-1.)
      H=1./(A-1.)
      BB=B*B
      ANUM=(((C*BB)/(1.+D*BB))**G)
      DEM=((E*BB-F)**H)
      ANORM = ANUM/DEM
      RETURN
      END
C
C
C
      FUNCTION FPMOPT( GAM , XM )
C      FUNCTION SUBPROGRAM TO CALCULATE P/PT * M CIRCLE
C      FROM GAMMA AND MACH NUMBER
C      DIMENSIONS = SEC * SQRT(K) / METRE
C
      FPMOPT = FMCIR ( GAM , XM ) * FPOPT ( GAM , XM )
      RETURN
      END
C
C
C
      SUBROUTINE SERCH (X,A,J,I,M)
C
      DIMENSION A(20)
      DO 10 L=1,I
      J=L
      IF (X.LE.A(L)) GO TO 20
   10 CONTINUE
   20 IF (J.EQ.1) GO TO 30
      J=J-1
   30 RETURN
      END
C
C
C
      FUNCTION SHOCK(XM,D)
C
```

```
C SHOCK FUNCTION SUBPROGRAM TO CALCULATE THE OBLIQUE SHOCK ANGLE FROM
C        THE WEDGE ANGLE AND MACH NUMBER
C         XM=MACH NUMBER  D=WEDGE ANGLE DELTA IN RADIANS
C        SHOCK=SHOCK ANGLE THETA IN RADIANS
C        P,Q,R,A,B=CONSTANTS  F=PHI WHICH IS AN INTERMEDIATE ANGLE
C         RADEG=TRANSFORMS RADIANS TO DEGREES
C
      RADEG = 57.2957795131
      SINZDZ=SIN(D)
      P=      -((XM*XM+2.)/(XM*XM)) -(1.4*SINZDZ*SINZDZ)
      DQ=1.44+(.4/(XM*XM))
      Q=((2.*XM*XM)+1.)/(XM*XM*XM*XM)+(DQ*SINZDZ*SINZDZ)
      C=COS(D)
      R=(-C*C)/(XM*XM*XM*XM)
      A=(1./3.)*(3.*Q-P*P)
      B=(1./27.)*(2.*P*P*P-9.*P*Q +27.*R)
      TEST = ((B*B)/4.)+ ((A*A*A)/27.)
      IF(TEST)1,1,2
    1 CONTINUE
      F = ARCOS((-B/2.)/SQRT((-1./27.)*A*A*A))
      FO=F*RADEG
      FOX=(FO/3.)+240.
      FOXE=FOX/RADEG
      X=2.*SQRT(-A/3.)*COS(FOXE)
      SHOCK = ARSIN(SQRT(X-P/3.))
      RETURN
    2 WRITE(6,3)
    3 FORMAT(48H NOW COME THE INPUTS TO SHOCK GIVE COMPLEX ROOTS)
      RETURN
      END
C
C
C
      FUNCTION STDLI (TBX,TBY,TAB,X,Y,NX,NY)
C
C                   FUNCTION DESIGNED TO ALLOW THE USER TO INPUT
C        VARIABLE LENGTH TABLES.  IT INTERPOLATES FIRST IN THE X
C        VARIABLE AND THEN IN THE Y VARIABLE.  IT EXTRAPOLATES FROM
C        THE FIRST OR LAST INTERVAL IF THE X OR Y IS OUTSIDE OF THE
C        BOUNDS OF THE TABLE.  IT REQUIRES THE SUBROUTINE SERCH FOR
C        ITS OPERATION.
C
C             PROGRAMMER -- H.SOBEL    30 OCTOBER 1967
C
      DIMENSION TBX(NX), TBY(NY), TAB(11,11)
      CALL SERCH (X,TBX,I,NX,1)
      CALL SERCH (Y,TBY,J,NY,1)
      XX=TBX(I)
```

```
      YY=TBY(J)                                                         D  30
      TXY=TAB(I,J)                                                      D  32
      XJ=TAB(I,J)+(X-TBX(I))*((TAB(I+1,J)-TAB(I,J))/(TBX(I+1)-TBX(I)))  D  34
      XJ1=TAB(I,J+1)+(X-TBX(I))*((TAB(I+1,J+1)-TAB(I,J+1))/(TBX(I+1)-TBX D  36
     1(I)))                                                             D  38
      STDL=XJ+(Y-TBY(J))*((XJ1-XJ)/(TBY(J+1)-TBY(J)))                   D  40
      STDL1=STDL                                                        D  42
   10 RETURN                                                            D  44
      END                                                               D  46-
C
C
C
      FUNCTION STDLIA (TBX,TBY,TAB,X,Y,NX,NY)                           F   2
C               FUNCTION DESIGNED TO ALLOW THE USER TO INPUT            F   4
C        VARIABLE LENGTH TABLES.  IT INTERPOLATES FIRST IN THE X        F   6
C        VARIABLE AND THEN IN THE Y VARIABLE.  IT EXTRAPOLATES FROM     F   8
C        THE FIRST OR LAST INTERVAL IF THE X OR Y IS OUTSIDE OF THE     F  10
C        BOUNDS OF THE TABLE.  IT REQUIRES THE SUBROUTINE SERCH FOR     F  12
C        ITS OPERATION.                                                 F  14
C                                                                       F  16
C             PROGRAMMER -- H.SOBEL     30 OCTOBER 1967                 F  18
C                                                                       F  20
      DIMENSION TBX(NX), TBY(NY), TAB(NX,NY)                            F  22
      CALL SERCH (X,TBX,I,NX,ID)                                        F  24
      CALL SERCH (Y,TBY,J,NY,JD)                                        F  26
      XJ=TAB(I,J)+(X-TBX(I))*((TAB(I+1,J)-TAB(I,J))/(TBX(I+1)-TBX(I)))  F  28
      XJ1=TAB(I,J+1)+(X-TBX(I))*((TAB(I+1,J+1)-TAB(I,J+1))/(TBX(I+1)-TBX F  30
     1(I)))                                                             F  32
      STDL1=XJ+(Y-TBY(J))*((XJ1-XJ)/(TBY(J+1)-TBY(J)))                  F  34
      STDLIA=STDL1                                                      F  36
   10 RETURN                                                            F  38
      END                                                               F  40-
C
C
C
      SUBROUTINE SUBSON(H,ZM,F,C,W,Q,A)
C
      C=.3
      SFC=3.0
      THR=.224809*C*Q*A
      WF=(SFC*THR)/3600.
      W=WF*.45359
      IF(W.LT.  0.0)W=-W
      RETURN
      END
C
C
```

```
C                                                                    VECM001C
      FUNCTICN VECMAG(X)
C
      CIMENSICN X(3)
   10 X2=X(1)*X(1)+X(2)*X(2)+X(3)*X(3)
      VECMAG=SCRT(X2)
      RETURN
      END
C
C
C
      FUNCTICN TC (T,ER,ATM)
C
C    THEORETICAL TEMPERATURE RISE CORRECTION FOR PRESSURES OTHER
C    THAN CNE ATMCSPHERE (HYCRCCARBON FUELS)
C
      DIMENSICN C(8), E(31), G(31,3), P(13), H(13,2)
      CATA C /-.129403E4,-.191763E3,.746699E2,-.434459E2,-.397487E2,-.26
     17021E2,.13558305E2,-.10890892E2/
      CATA E /.0,.C5,.1,.15,.2,.25,.3,.35,.4,.45,.5,.55,.6,.65,.7,.75,.8
     1,.85,.9,.95,1.,1.05,1.1,1.15,1.2,1.25,1.3,1.35,1.4,1.45,1.5/
      CATA G /C.,.000052,-.000C7,-.000258,-.00084,-.001837,-.00407,-.0C7
     1901,-.01473,-.025548,-.04194,-.065907,-.09719,-.136621,-.18292,-.2
     236296,-.29312,-.351881,-.40644,-.453286,-.48303,-.481847,-.45954,-
     3.418049,-.36713,-.31690,-.26822,-.225566,-.18821,-.157010,-.13168
     4,0.,.000144,-.00045,-.C01341,-.00385,-.C0825,-.01724,-.032921,-.0
     55722,-.C93804,-.13956,-.198405,-.25292,-.291575,-.30062,-.263938,-
     6.17710,-.C14879,.17645,.395969,.53284,.429298,.22521,-.007856,-.22
     7277,-.332987,-.38518,-.391398,-.36897,-.341909,-.30221,C.,.000244,
     8.0C173,.CC3242,.00843,.019739,.03957,.071769,.11444,.173804,.22936
     9,.270517,.27377,.2C1127,.08546,-.084450,-.21432,-.205284,-.08215,.
     A284744,.53085,.162602,-.30329,-.468888,-.47144,-.264349,-.00121,.1
     B63745,.279C3,.341386,.351907
      CATA P /.20,.35,.5C,.75,1.0,1.5,2.0,3.5,5.0,7.5,10.,15.,20./
      CATA H /.44161,.297035,.18097,.066615,0.,-.102718,-.16656,-.298846
     1,-.36320,-.446764,-.49337,-.574833,-.60759,-.80970,-.477316,-.2282
     27,-.C48428,0.,.075181,.08051,.061939,-.02264,-.121555,-.21910,-.37
     33927,-.48712/
C
C    CHECK FCR ENTRY OUTSICE LATTICE
C
      IF (T.LT.298.) GO TC 50
      IF (T.GT.1300.) GO TC 60
      IF (ER.GT.1.5) GC TC 70
      IF (ATM.LT..2) GO TC 90
      IF (ATM.GT.20.) GO TC 80
C
C    CCMPUTE FACTCR ANALYSIS FACTORS F1,F2,F3
```

```
C
      F1=-((.227276E-3+.100807E-6*T)*T+.018785)
      F2=(.00120097-.1254E-5*T)*T+.0846043
      F3=(((.113312E-7-.244175E-11*T)*T-.141615E-4)*T+.00496299)*T+.0056
     A0473
C
C   LINEARLY INTERPOLATE FOR FACTORS G1,G2,G3
C
      DO 10 I=1,31
      IF (ER.LE.E(I)) GO TO 20
 10   CONTINUE
  20  J=I-1
      R=(ER-E(J))/(E(I)-E(J))
      G1=G(J,1)+(G(I,1)-G(J,1))*R
      G2=G(J,2)+(G(I,2)-G(J,2))*R
      G3=G(J,3)+(G(I,3)-G(J,3))*R
C
C   LINEARLY INTERPOLATE FOR FACTORS H1,H2
C
      DO 30 I=1,13
      IF (ATM.LE.P(I)) GO TO 40
 30   CONTINUE
  40  J=I-1
      R=(ATM-P(J))/(P(I)-P(J))
      H1=H(J,1)+(H(I,1)-H(J,1))*R
      H2=H(J,2)+(H(I,2)-H(J,2))*R
C
C   COMPUTE TEMPERATURE CORRECTION (TC)
C
      TC=C(1)*F1*G1*H1+C(2)*F2*G2*H1+C(3)*F1*G2*H2+C(4)*F2*G1*H2
     D          + C(5)*F3*G3*H1
     E          + C(6)*F2*G3*H2
     F          + C(7)*F3*G2*H2
     G          + C(8)*F1*G3*H2
C
      RETURN
  50  WRITE (6,110)
      GO TO 100
  60  WRITE (6,120)
      GO TO 100
  70  WRITE (6,130)
      GO TO 100
  80  WRITE (6,150)
      GO TO 100
  90  WRITE (6,140)
 100  CALL EXIT
      RETURN
C
```

```
 110   FORMAT ('0 TOTAL TEMPERATURE LESS THAN 298 K. END RUN.')
 120   FORMAT ('0  TOTAL TEMPERATURE GREATER THAN 1300 K. END RUN.')
 130   FORMAT ('0 FUEL EQUIVALENCE RATIO EXCEEDS 1.5 END OF RUN.')
 140   FORMAT ('0 ATMOSPHERIC PRESSURE LESS THAN 0.2, END OF RUN.')
 150   FORMAT ('0 ATMOSPHERIC PRESSURE EXCEEDS 20, END OF RUN.')
       END
C
C
C
       FUNCTION ODLI (A,X,F,N)                                                 E   2
C
       DIMENSION X(N), F(N)                                                    E   4
       IF (N-2) 50,10,10                                                       E   6
    10 IF (X(1).EQ.X(N)) GO TO 60                                              E   8
       IF (X(1).EQ.X(2).OR.X(N-1).EQ.X(N)) GO TO 70                            E  10
       CALL SERCH (A,X,I,N,D)                                                  E  12
       IF (A.NE.X(I+1)) GO TO 30                                               E  14
       IF (X(I+1)-X(I+2)) 20,40,20                                             E  16
    20 ODLI=F(I+1)                                                             E  18
       RETURN                                                                  E  20
    30 ODLI=F(I)+(A-X(I))*(F(I+1)-F(I))/(X(I+1)-X(I))                          E  22
       RETURN                                                                  E  24
    40 ODLI=0.5*(F(I+1)+F(I+2))                                                E  26
       RETURN                                                                  E  28
    50 WRITE (6,90)                                                            E  30
       GO TO 80                                                                E  32
    60 WRITE (6,100)                                                           E  34
       GO TO 80                                                                E  36
    70 WRITE (6,110)                                                           E  38
    80 CALL EXIT                                                               E  40
    90 FORMAT (1H1,10X,57HERROR IN SUBROUTINE ODLI, TABLE HAS LESS THAN T      E  44
      1WO ENTRIES)                                                             E  46
   100 FORMAT (1H1,10X,60HERROR IN SUBROUTINE ODLI, INITIAL AND FINAL POI      E  48
      1NTS ARE EQUAL)                                                          E  50
   110 FORMAT (1H1,10X,59HERROR IN SUBROUTINE ODLI, DISCONTINUITY AT ONE       E  52
      1END OF TABLE)                                                           E  54
       END                                                                     E  56-
                                                                               E  42
C
C
C
       SUBROUTINE INTR20(X1,X2,D,O,L)
C
       DIMENSION D(1000)
       X=X1
       Y=X2
       N1 =D(1)
       N2=O(2)
       IX1=N1+2
```

```
      DO 10 II=4,IX1
      I=II
      IF(X.LT.C(I)) GO TO 11
   10 CONTINUE
   11 IO =I-2
      IX2= N1+4
      IX3=IX1+N2
      DO 20 JJ=IX2,IX3
      J=JJ
      IF(Y.LT.C(J)) GO TO 21
   20 CONTINUE
   21 JO=J-IX1
      NA=IX3+N2*((L-1)*N1+IO-2)+JO-1
      F1=(X-C(I-1))/(C(I)-C(I-1))
      F2=(Y-C(J-1))/(C(J)-C(J-1))
      F3=F1*F2
      C= C(NA)*(1.-F1-F2+F3)
     1  + C(NA+N2)*(F1-F3)
     2  + C(NA+1)*(F2-F3)
     3  + C(NA+N2+1)*F3
      RETURN
      END
C
C
C
      FUNCTION THREDL (X,Y,Z,AX,AY,AZ,AXYZ,NX,NY,NZ)                    F    2
C
C        THIS FUNCTION INTERPOLATES LINEARLY IN THREE DIMENSIONS.  IT   F    4
C     SELECTS THE TWO PLANES OF COSTANT Z AND USES STDLI FOR TWO DIMEN- F    6
C     SIONAL INTERPOLATION.  A LINEAR INTERPOLATION IS USED IN Z.       F    8
C        PROGRAMMER  H.SOBEL                 DATE  22 AUGUST 1968       F   10
      DIMENSION AX(NX), AY(NY), AZ(NZ), AXYZ(NX,NY,NZ)                  F   12
      DATA M/1/                                                         F   14
      CALL SERCH (Z,AZ,K,NZ,M)                                          F   16
      AL=STDLIA(AX,AY,AXYZ(1,1,K),X,Y,NX,NY)                            F   18
      AU=STDLIA(AX,AY,AXYZ(1,1,K+1),X,Y,NX,NY)                          F   20
      THREDL=AL+(AU-AL)*(Z-AZ(K))/(AZ(K+1)-AZ(K))                       F   22
      RETURN                                                            F   24
      END                                                               F   26-
```

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